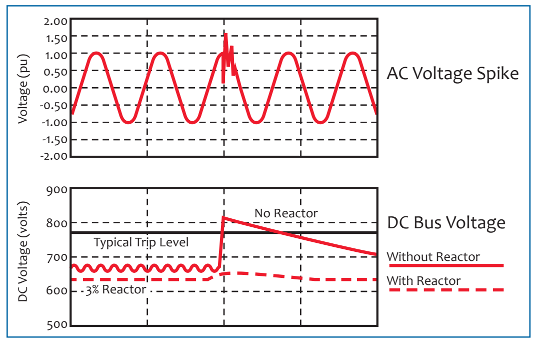
AN SL POWER ELECTRONICS COMPANY

RL Line/Load Reactors

Selection Table, Technical Details & Product Application Guide

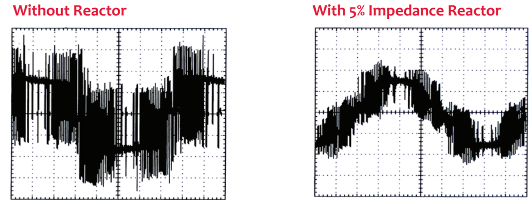
MTE HARMONIC COMPENSATED LINE/LOAD REACTORS help keep your equipment running longer by absorbing many of the power line disturbances which otherwise damage or shut down your inverters, variable frequency drives (VFDs), variable speed controllers, or other sensitive equipment. They are a robust filtering solution for virtually any 6 pulse rectifier or power conversion unit. There is no need to de-rate MTE Reactors as they are harmonic compensated and IGBT protected to assure optimum performance in the presence of harmonics, and are very effective at reducing harmonics produced by inverters and drives. Standard MTE Reactors may be applied up to 690 VAC with compatible impedance ratings. MTE RL Reactors have higher continuous and overload ratings.

VOLTAGE SPIKE PROTECTION - Voltage spikes on the AC power lines cause rapid elevation of the DC Bus voltage which may cause the inverter to “trip-off” and indicate an over-voltage protection condition. RL Reactors absorb these line spikes and offer protection to the rectifiers and DC Bus capacitors while minimizing nuisance tripping of the inverter. A 3% impedance RL Reactor is 90% effective at protecting against transients or nuisance tripping of AC voltage source inverters due to voltage spikes. The 5% RL Reactor extends spike protection to 99%.



MOTOR PROTECTION - MTE RL Reactors help to protect motors and cables from the high peak voltages and fast rise times (dV/dt) which can be experienced in IGBT inverter applications when the distance between the inverter and motor is up to 300 feet. For guaranteed long lead protection up to 1000 feet use the MTE **dV/dt Filter** or the MTE **Sine Wave Filter** as the ultimate in motor and wire protection.

Without Reactor / With 5% Impedance Reactor



HARMONICS:

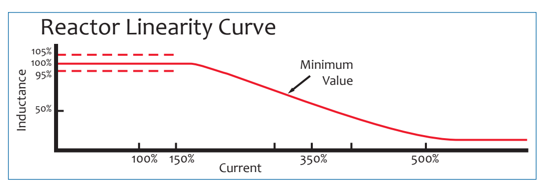
Drive Harmonic currents will be reduced by adding an input line reactor.

3% impedance reactor yields 35-55% THID

5% impedance reactor yields 25-45% THID

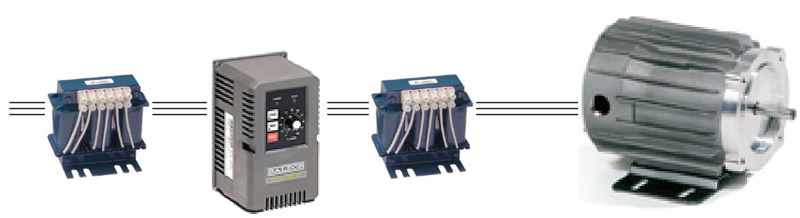
Note: for guaranteed compliance to IEEE519 (5% THID) use a MTE Matrix Series D Filter

REACTOR LOADED PERFORMANCE: The curve to the right illustrates the linearity of MTE RL Reactors. Even at 150% of their rated current, these reactors still have 100% of their nominal inductance. This assures maximum filtering of distortion even in the presence of severe harmonics and the best absorption of surges. The typical tolerance on rated inductance is plus-or-minus 10%.



Typical uses include:

- Protect Motors from Long Lead Effects
- Reduce Output Voltage dV/dt
- Virtually Eliminate Nuisance Tripping
- Extend Semiconductor Life
- Reduce Harmonic Distortion
- Reduce Motor Temperature
- Reduce Motor Audible Noise



For three phase applications you can use the same MTE catalog part number to protect both line and load side of a VFD.

MTE RL Reactor Selection Tables

Selection Table 208-690 VAC Three-Phase and Single-Phase Applications

	Input Voltage	% Impedance	0.25hp 0.18kw	0.33hp 0.25kw	0.5hp 0.37kw	0.75hp 0.55kw	1hp 0.75kw	1.5hp 1.1kw	2hp 1.5kw	3hp 2.2kw	5hp 3.7kw	7.5hp 5.5kw	10hp 7.5kw	15hp 11kw	20hp 15kw	25hp 18.5kw
Three Phase input or output applications selected by Motor	208 vac 60Hz	3%	RL-00204	RL-00204	RL-00401	RL-00401	RL-00802	RL-00801	RL-01201	RL-01801	RL-02501	RL-03501	RL-04501	RL-05501	RL-08001	RL-10001
		5%	RL-00201	RL-00201	RL-00402	RL-00803	RL-00802	RL-00802	RL-01202	RL-01802	RL-02502	RL-03502	RL-05502	RL-08002	RL-10002	RL-08001
	240 vac 60Hz	3%	RL-00201	RL-00204	RL-00204	RL-00401	RL-00401	RL-00801	RL-00801	RL-01201	RL-01801	RL-02501	RL-03501	RL-04501	RL-08001	RL-10001
		5%	RL-00202	RL-00201	RL-00403	RL-00402	RL-00803	RL-00802	RL-00802	RL-01202	RL-01802	RL-03502	RL-03502	RL-05502	RL-08002	RL-10002
	400 vac 50Hz	3%	RL-00103	RL-00103	RL-00202	RL-00202	RL-00201	RL-00403	RL-00402	RL-00803	RL-01202	RL-01202	RL-01802	RL-02502	RL-03502	RL-04502
		5%	RL-00102	RL-00102	RL-00203	RL-00203	RL-00202	RL-00404	RL-00404	RL-00804	RL-01203	RL-01203	RL-01803	RL-02503	RL-03503	RL-04503
	480 vac 60Hz	3%	RL-00103	RL-00103	RL-00104	RL-00201	RL-00201	RL-00402	RL-00402	RL-00803	RL-00802	RL-01202	RL-01802	RL-02502	RL-03502	RL-03502
		5%	RL-00102	RL-00102	RL-00103	RL-00202	RL-00202	RL-00404	RL-00404	RL-00804	RL-00803	RL-01203	RL-01803	RL-02503	RL-03503	RL-03503
	600 vac 60Hz	3%	RL-00102	RL-00102	RL-00103	RL-00202	RL-00202	RL-00201	RL-00403	RL-00402	RL-00803	RL-01202	RL-01202	RL-01802	RL-02502	RL-02502
		4%	RL-00101	RL-00101	RL-00102	RL-00203	RL-00203	RL-00202	RL-00404	RL-00404	RL-00804	RL-01203	RL-01203	RL-01803	RL-02503	RL-02503
	690 vac 50Hz	2%								RL-00403	RL-00402	RL-00801	RL-01202	RL-01202	RL-01802	RL-02502
		3%								RL-00402	RL-00404	RL-00804	RL-01203	RL-01203	RL-01803	RL-02503
Single Phase input Applications	*Use outer two windings*															
	120 vac 60Hz	5%	*RL-00801*	*RL-001201*	*RL-01801*	*RL-02501*	*RL-02501*	*RL-03503*	*RL-03501*	*RL-05501*	*RL-10001*	*RL-13001*	*RL-13001*			
	208 vac 60Hz	5%	*RL-00401*	*RL-00401*	*RL-00401*	*RL-01202*	*RL-00801*	*RL-01201*	*RL-02502*	*RL-03502*	*RL-03501*	*RL-04501*	*RL-05501*	*RL-08001*	*RL-13001*	*RL-13001*
	240 vac 60Hz	5%	*RL-00402*	*RL-00401*	*RL-00803*	*RL-00802*	*RL-01202*	*RL-01201*	*RL-01201*	*RL-01801*	*RL-04502*	*RL-08002*	*RL-08002*	*RL-08001*	*RL-10001*	*RL-16002*
	240 vac 50Hz	5%	*RL-hp*	*RL-00402*	*RL-00402*	*RL-00802*	*RL-00802*	*RL-01802*	*RL-01802*	*RL-02502*	*RL-03502*	*RL-05502*	*RL-08002*	*RL-10002*	*RL-13002*	*RL-16002*
	400 vac 50Hz	5%	*RL-00103*	*RL-00202*	*RL-00201*	*RL-00201*	*RL-00403*	*RL-00402*	*RL-00803*	*RL-01203*	*RL-01803*	*RL-02503*	*RL-03503*	*RL-04502*	*RL-05502*	*RL-08002*
	480 vac 60Hz	5%	*RL-00202*	*RL-00202*	*RL-00202*	*RL-00404*	*RL-00403*	*RL-00402*	*RL-00803*	*RL-01203*	*RL-01803*	*RL-02503*	*RL-02502*	*RL-05503*	*RL-08003*	*RL-08003*
	600 vac 60 Hz	5%			*RL-00202*	*RL-00202*	*RL-00404*	*RL-00403*	*RL-00403*	*RL-00803*	*RL-01203*	*RL-01803*	*RL-02503*	*RL-03503*	*RL-04503*	*RL-05503*

For detailed product specifications refer to the RL User Manual or RL Reference Sheet.

This table is suitable for selection of both input & output 3-phase reactors because their harmonic compensation & conservative design allow them to be used in either application. Specific current & inductance ratings are indicated on Pages 4 & 5. Consult factory for any special applications (higher current, motor rating different than controller rating, etc).

Select RL line/load reactors based upon motor horsepower (or kilowatts) and voltage. Verify that the motor full load ampere name plate rating is within the RMS current rating of the reactor, & the drive/inverter rating is within the maximum continuous current rating of the reactor

Agency Approvals:

MTE RL Reactors are manufactured to the exacting standards of MIL-I-45208, VDE-0550, & are UL Listed and CSA certified. All UL approvals are for USA & Canada.

- **CSA File #LR29753-13, open units up to 2400A**
- **UL-508 File #E180243, open and enclosed up to 2400A**

NEMA Cabinets:

RL reactors are available as either open type or in a NEMA Type 1 general purpose enclosure or NEMA type 3R weather. To order a reactor mounted in a cabinet simply change the second last digit of the part number from "0" to "1" (NEMA1) or "3" for (NEMA 3R) Cabinets.
Example: RL-00802 enclosed becomes RL-00812.

Impedance Rating:

3% impedance reactors are typically sufficient to absorb power line spikes and motor current surges. They will prevent nuisance tripping of drives or circuit breakers in most applications.

5% impedance reactors are best for reducing harmonic currents and frequencies. Use them when you must reduce VFD drive generated harmonics, and to reduce motor operating temperature, or to reduce motor noise.

$$\%_{impedance} = \frac{I_{RMS} \times 2\pi F_{50/60Hz} \times L_{RLinductance} \times \sqrt{3}}{V_{L\text{-}L}} \times 100$$

Note: The effective impedance of the reactor changes with actual RMS current through the reactor as seen in the above equation.

A 5% impedance reactor becomes 3% if its current is reduced to 60%.

Selection Table 208-690 VAC Three-Phase and Single-Phase Applications ... *Continued*

30hp 22kw	40hp 30kw	50hp 37.5kw	60hp 45kw	75hp 55kw	100hp 75kw	125hp 93kw	150hp 112kw	200hp 150kw	250hp 187kw	300hp 225kw	350hp 262kw	400hp 300kw	500hp 375kw	600hp 450kw	700hp 550kw	800hp 600kw
RL-13001	RL-13001	RL-16001	RL-20001B14	RL-25001B14	RL-32001B14	RL-50001B14	RL-50001B14	RL-60001	RL-75001	RL-85001B14	RL-100001B14	RL-120001B14	RL-40001			
RL-10001	RL-13001	RL-16001	RL-20002B14	RL-25002B14	RL-32001B14	RL-50002	RL-60002	RL-60001	RL-75002	RL-85001B14	RL-100002B14	RL-120002B14	RL-40001			
RL-10001	RL-13001	RL-13001	RL-16001	RL-20001B14	RL-25001B14	RL-32001B14	RL-40001B14	RL-50001B14	RL-60001	RL-75001	RL-85001B14	RL-100001B14	RL-120001B14			
RL-10002	RL-13002	RL-13001	RL-16002	RL-20002B14	RL-25002B14	RL-32002B14	RL-40002B14	RL-50002	RL-60002	RL-75002	RL-85002B14	RL-100002B14	RL-120002B14			
RL-04502	RL-05502	RL-08002	RL-10002	RL-13002	RL-16002	RL-20002B14	RL-25002B14	RL-32002B14	RL-40002B14	RL-40002B14	RL-50002	RL-60002	RL-75002	RL-90002B14	RL-100002B14	RL-120002B14
RL-04503	RL-05503	RL-08003	RL-10003	RL-13003	RL-16003	RL-20003B14	RL-25003B14	RL-32003B14	RL-40003B14	RL-40003B14	RL-50003	RL-60003	RL-75003	RL-90003B14	RL-100003B14	RL-120003B14
RL-04502	RL-05502	RL-08002	RL-08002	RL-10002	RL-13002	RL-16002	RL-20002B14	RL-25002B14	RL-32002B14	RL-40002B14	RL-50002	RL-50002	RL-60002	RL-75002	RL-85002B14	RL-100002B14
RL-04503	RL-05503	RL-08003	RL-08003	RL-10003	RL-13003	RL-16003	RL-20003B14	RL-25003B14	RL-32003B14	RL-40003B14	RL-50003	RL-50003	RL-60003	RL-75003	RL-85003B14	RL-100003B14
RL-03502	RL-04502	RL-05502	RL-08002	RL-08002	RL-10002	RL-13002	RL-16002	RL-20002B14	RL-25002B14	RL-32002B14	RL-40002B14	RL-40002B14	RL-50002	RL-60002	RL-75002	RL-85002B14
RL-03503	RL-04503	RL-05503	RL-08003	RL-08003	RL-10003	RL-13003	RL-16003	RL-20003B14	RL-25003B14	RL-32003B14	RL-40003B14	RL-40003B14	RL-50003	RL-60003	RL-75003	RL-85003B14
RL-02502	RL-02501	RL-03501	RL-04502	RL-05502	RL-08002	RL-08002	RL-10002	RL-13002	RL-13002	RL-16002	RL-20002B14	RL-25002B14	RL-32002B14	RL-40002B14	RL-40002B14	RL- RL-50002
RL-02503	RL-02503	RL-03503	RL-04503	RL-05503	RL-08003	RL-08002	RL-10003	RL-13003	RL-13003	RL-16003	RL-20003B14	RL-25003B14	RL-32003B14	RL-40003B14	RL-40003B14	RL- RL-50003
Use outer two windings																
RL-16001	*RL-20001B14*	*RL-25001B14*	*RL-32001B14*	*RL-40001B14*	*RL-50001B14*											
RL-20002B14	*RL-25002B14*	*RL-32002B14*	*RL-40002B14*	*RL-50002*	*RL-60002*											
RL-16002	*RL-20002B14*	*RL-25002B14*	*RL-32002B14*	*RL-40002B14*	*RL-75003*											
RL-08002	*RL-10002*	*RL-13003*	*RL-16003*	*RL-20003B14*	*RL-25003B14*											
RL-08003	*RL-10002*	*RL-13003*	*RL-16003*	*RL-20003B14*	*RL-25003B14*	*RL-32003B14*	*RL-40003B14*	*RL-50003*								
RL-08003	*RL-08002*	*RL-10003*	*RL-13003*	*RL-16003*	*RL-20003B14*	*RL-25003B14*	*RL-25003B14*	*RL-40003B14*								

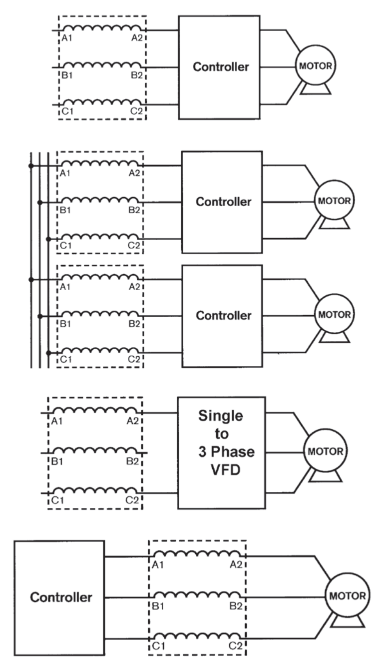
Standard Application of RL Line/Load Reactors:

On the input of motor VFD controller or six-pulse nonlinear load, RL Reactors protect sensitive electronic equipment from electrical noise created by the drive or inverter (notching, pulsed distortion or harmonics). RL Reactors protect the controller from surges or spikes on the incoming power lines and reduce harmonic distortion. They help to reduce VFD produced non-linear current harmonics that may cause voltage distortion and effect other devices powered from the same AC mains.

Multiple drives or inverters on a common power line require one reactor per controller. Individual reactors provide filtering between each controller (reducing crosstalk) and also provide optimum surge protection for each unit. A single reactor serving several controllers does not provide adequate protection, filtering or harmonic reduction when the system is partially loaded.

Single Phase input configured drives can be protected from spikes and transient voltage by using standard 3-phase RL Line/Load Reactors for 1- phase applications by routing each of the two supply conductors through an outside coil and leaving the center open. Application Note **AN0102** details this use. Note that the single drive input current is $\sqrt{3}$ (SQRT 3) times the 3-phase motor values. The above table may be used to select a reactor for 1-phase input applications.

In extended motor lead applications up to 300 feet use RL Reactors between the inverter & motor to reduce dV/dT & motor terminal peak voltage. The use of a separate load reactor also protects the controller from surge current caused by a rapid change in the load, & even from a short circuit at the load. MTE Reactors also reduce operating temperature & audible noise in motor loads. For a guaranteed long lead solution up to 1000 feet use the **MTE Series A dV/dT Filter**. More than one motor on a single drive presents a complex load not suited to reactor protection. Use an **MTE Series A Sine Wave Filter** when there is a need to protect more than one motor or for single motor distances to 15,000 feet.



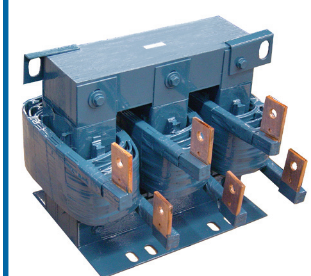
Selection Table RL Line/Load Reactor Technical Data

Open Part	amps	Inductance mH	Watts	Size inches	Size mm	Open Weight	Cabinet
RL-00101	1	100	13.5	3.5 in H x 3.8 in W x 1.2 in D	89 mm H x 97 mm W x 30 mm D	2.2# 1Kg	CAB-8
RL-00102	1	50	12.8	3.5 in H x 3.8 in W x 1.2 in D	89 mm H x 97 mm W x 30 mm D	2.1# 1Kg	CAB-8
RL-00103	1	36	11.9	3.5 in H x 3.8 in W x 1.2 in D	89 mm H x 97 mm W x 30 mm D	2.1# 1Kg	CAB-8
RL-00104	1	18	9.6	3.5 in H x 3.8 in W x 1.2 in D	89 mm H x 97 mm W x 30 mm D	2# 0.9Kg	CAB-8
RL-00201	2	12	7.5	4.1 in H x 4.4 in W x 2.8 in D	104 mm H x 112 mm W x 71 mm D	4# 1.8Kg	CAB-8
RL-00202	2	20	11.3	4.1 in H x 4.4 in W x 2.8 in D	104 mm H x 112 mm W x 71 mm D	4# 1.8Kg	CAB-8
RL-00203	2	32	16	4.1 in H x 4.4 in W x 2.8 in D	104 mm H x 112 mm W x 71 mm D	4# 1.8Kg	CAB-8
RL-00204	2	6	10.7	4.1 in H x 4.4 in W x 2.5 in D	104 mm H x 112 mm W x 64 mm D	3# 1.4Kg	CAB-8
RL-00401	4	3	14.5	4.1 in H x 4.4 in W x 2.8 in D	104 mm H x 112 mm W x 71 mm D	4# 1.8Kg	CAB-8
RL-00402	4	6.5	20	4.1 in H x 4.4 in W x 2.8 in D	104 mm H x 112 mm W x 71 mm D	4# 1.8Kg	CAB-8
RL-00403	4	9	20	4.1 in H x 4.4 in W x 3.4 in D	104 mm H x 112 mm W x 86 mm D	5# 2.3Kg	CAB-8
RL-00404	4	12	21	4.1 in H x 4.4 in W x 3.4 in D	104 mm H x 112 mm W x 86 mm D	6# 2.7Kg	CAB-8
RL-00801	8	1.5	19.5	4.8 in H x 6 in W x 3 in D	122 mm H x 152 mm W x 76 mm D	7# 3.2Kg	CAB-8
RL-00802	8	3	29	4.8 in H x 6 in W x 3 in D	122 mm H x 152 mm W x 76 mm D	8# 3.6Kg	CAB-8
RL-00803	8	5	25.3	4.8 in H x 6 in W x 3.4 in D	122 mm H x 152 mm W x 86 mm D	11# 5Kg	CAB-8
RL-00804	8	7.5	28	4.8 in H x 6 in W x 3.4 in D	122 mm H x 152 mm W x 86 mm D	13# 5.9Kg	CAB-8
RL-01201	12	1.25	26	5 in H x 6 in W x 3.3 in D	127 mm H x 152 mm W x 84 mm D	9# 4.1Kg	CAB-8
RL-01202	12	2.5	31	5 in H x 6 in W x 3.3 in D	127 mm H x 152 mm W x 84 mm D	10# 4.5Kg	CAB-8
RL-01203	12	4.2	41	5 in H x 6 in W x 3.9 in D	127 mm H x 152 mm W x 99 mm D	18# 8.2Kg	CAB-8
RL-01801	18	0.8	36	5.3 in H x 6 in W x 3.2 in D	135 mm H x 152 mm W x 81 mm D	9# 4.1Kg	CAB-8
RL-01802	18	1.5	43	5.3 in H x 6 in W x 3.5 in D	135 mm H x 152 mm W x 89 mm D	12# 5.4Kg	CAB-8
RL-01803	18	2.5	43	6.1 in H x 8.1 in W x 4 in D	155 mm H x 206 mm W x 102 mm D	16# 7.3Kg	CAB-13V
RL-02501	25	0.5	48	5.8 in H x 7.2 in W x 3.5 in D	147 mm H x 183 mm W x 89 mm D	11# 5Kg	CAB-13V
RL-02502	25	1.2	52	5.8 in H x 7.2 in W x 3.5 in D	147 mm H x 183 mm W x 89 mm D	14# 6.4Kg	CAB-13V
RL-02503	25	1.8	61	5.8 in H x 7.2 in W x 4.3 in D	147 mm H x 183 mm W x 109 mm D	20# 9.1Kg	CAB-13V
RL-03501	35	0.4	49	5.8 in H x 7.2 in W x 4 in D	147 mm H x 183 mm W x 102 mm D	14# 6.4Kg	CAB-13V
RL-03502	35	0.8	54	5.8 in H x 7.2 in W x 4 in D	147 mm H x 183 mm W x 102 mm D	16# 7.3Kg	CAB-13V
RL-03503	35	1.2	54	7.4 in H x 9 in W x 4.7 in D	188 mm H x 229 mm W x 119 mm D	30# 13.6Kg	CAB-13V
RL-04501	45	0.3	54	7.4 in H x 9 in W x 4.7 in D	188 mm H x 229 mm W x 119 mm D	23# 10.4Kg	CAB-13V
RL-04502	45	0.7	62	7.4 in H x 9 in W x 4.7 in D	188 mm H x 229 mm W x 119 mm D	28# 12.7Kg	CAB-13V
RL-04503	45	1.2	65	7.3 in H x 9 in W x 5.3 in D	185 mm H x 229 mm W x 135 mm D	39# 17.7Kg	CAB-13V
RL-05501	55	0.25	64	7.3 in H x 9 in W x 5.3 in D	185 mm H x 229 mm W x 135 mm D	24# 10.9Kg	CAB-13V
RL-05502	55	0.5	67	7 in H x 9 in W x 5.3 in D	178 mm H x 229 mm W x 135 mm D	27# 12.2Kg	CAB-13V
RL-05503	55	0.85	71	7 in H x 9 in W x 6 in D	178 mm H x 229 mm W x 152 mm D	41# 18.6Kg	CAB-13V
RL-08001	80	0.2	82	7.2 in H x 9 in W x 6.3 in D	183 mm H x 229 mm W x 160 mm D	25# 11.3Kg	CAB-13V
RL-08002	80	0.4	86	7.2 in H x 9 in W x 6.5 in D	183 mm H x 229 mm W x 165 mm D	33# 15Kg	CAB-13V
RL-08003	80	0.7	96	8.5 in H x 10.8 in W x 6.8 in D	216 mm H x 274 mm W x 173 mm D	61# 27.7Kg	CAB-13V
RL-10001	100	0.15	94	7.3 in H x 9 in W x 6.5 in D	185 mm H x 229 mm W x 165 mm D	29# 13.2Kg	CAB-13V
RL-10002	100	0.3	84	7.3 in H x 9 in W x 6.8 in D	185 mm H x 229 mm W x 173 mm D	37# 16.8Kg	CAB-13V
RL-10003	100	0.45	108	8.25 in H x 10.8 in W x 6.16 in D	210 mm H x 274 mm W x 156 mm D	74# 33.6Kg	CAB-13V

Specifications subject to change without notice

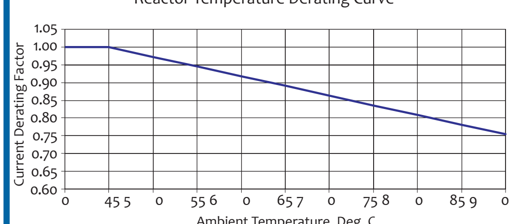
MTE RL Reactors can be supplied in a variey of standard enclosures or open frame type to enable you to mount them in your sytem in the most efficient manner

RL-10012

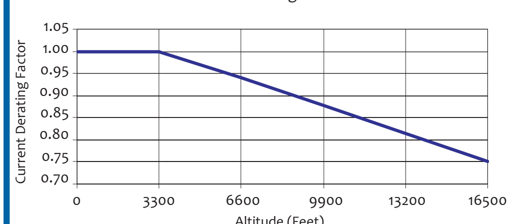


RL-50003

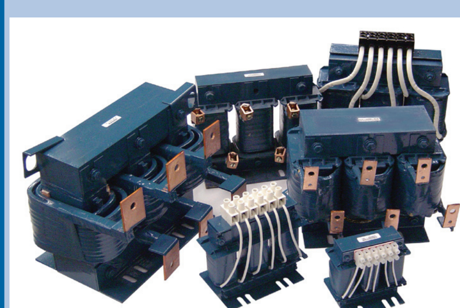
Reactor Temperature Derating Curve



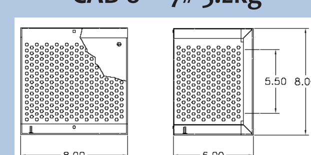
Altitude Derating Curve



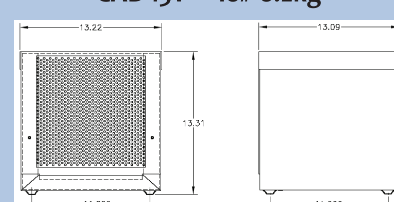
MTE RL Reactors connection types and terminals vary by model and rating



CAB-8 - 7# 3.2kg



CAB-13V - 18# 8.2kg



The Global Power Quality Resource

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Selection Table **RL Line/Load Reactor Technical Data** *... Continued*

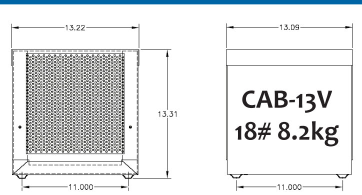
Open Part	amps	Inductance mH	Watts	Size inches	Size mm	Open Weight	Cabinet
RL-13001	130	0.1	108	7 in H x 9 in W x 4.66 in D	178 mm H x 229 mm W x 118 mm D	29# 13.2Kg	CAB-13V
RL-13002	130	0.2	180	7.2 in H x 9 in W x 6.8 in D	183 mm H x 229 mm W x 173 mm D	43# 19.5Kg	CAB-13V
RL-13003	130	0.3	128	8.5 in H x 11 in W x 6.16 in D	216 mm H x 279 mm W x 156 mm D	64# 29Kg	CAB-13V
RL-16001	160	0.075	116	7.2 in H x 9 in W x 6.8 in D	183 mm H x 229 mm W x 173 mm D	41# 18.6Kg	CAB-13V
RL-16002	160	0.15	149	8.3 in H x 10.8 in W x 6 in D	211 mm H x 274 mm W x 152 mm D	50# 22.7Kg	CAB-13V
RL-16003	160	0.23	138	8.5 in H x 11.5 in W x 9 in D	216 mm H x 292 mm W x 229 mm D	67# 30.4Kg	CAB-13V
RL-20001B14	200	0.055	124	7.5 in H x 9 in W x 7.3 in D	191 mm H x 229 mm W x 185 mm D	38# 17.2Kg	CAB-13V
RL-20002B14	200	0.11	168	7.5 in H x 9 in W x 8.3 in D	191 mm H x 229 mm W x 211 mm D	54# 24.5Kg	CAB-13V
RL-20003B14	200	0.185	146	8.3 in H x 10.8 in W x 10 in D	211 mm H x 274 mm W x 254 mm D	100# 45.4Kg	CAB-13V
RL-25001B14	250	0.045	154	7.5 in H x 9 in W x 9 in D	191 mm H x 229 mm W x 229 mm D	47# 21.3Kg	CAB-13V
RL-25002B14	250	0.09	231	8.5 in H x 10.8 in W x 9 in D	216 mm H x 274 mm W x 229 mm D	80# 36.3Kg	CAB-17V
RL-25003B14	250	0.15	219	11.2 in H x 14.4 in W x 10.3 in D	284 mm H x 366 mm W x 262 mm D	125# 56.7Kg	CAB-17V
RL-32001B14	320	0.04	224	9 in H x 10.8 in W x 8.3 in D	229 mm H x 274 mm W x 211 mm D	80# 36.3Kg	CAB-17V
RL-32002B14	320	0.075	264	9 in H x 10.8 in W x 10 in D	229 mm H x 274 mm W x 254 mm D	102# 46.3Kg	CAB-17V
RL-32003B14	320	0.125	351	11.25 in H x 14.4 in W x 10.5 in D	286 mm H x 366 mm W x 267 mm D	160# 72.6Kg	CAB-17V
RL-40001B14	400	0.03	231	10 in H x 10.8 in W x 10 in D	254 mm H x 274 mm W x 254 mm D	84# 38.1Kg	CAB-17V
RL-40002B14	400	0.06	333	11.25 in H x 15 in W x 11.5 in D	286 mm H x 381 mm W x 292 mm D	118# 53.5Kg	CAB-17V
RL-40003B14	400	0.105	293	11.25 in H x 14.4 in W x 12.5 in D	286 mm H x 366 mm W x 318 mm D	149# 67.6Kg	CAB-17V
RL-50001B14	500	0.025	266	9 in H x 10.8 in W x 10.5 in D	229 mm H x 274 mm W x 267 mm D	93# 42.2Kg	CAB-17V
RL-50002	500	0.05	340	11.5 in H x 14.4 in W x 11.5 in D	292 mm H x 366 mm W x 292 mm D	118# 53.5Kg	CAB-26C
RL-50003	500	0.085	422	11.5 in H x 14.4 in W x 13.3 in D	292 mm H x 366 mm W x 338 mm D	210# 95.3Kg	CAB-26C
RL-60001	600	0.02	307	11.5 in H x 14.4 in W x 10 in D	292 mm H x 366 mm W x 254 mm D	120# 54.4Kg	CAB-26C
RL-60002	600	0.04	414	11.25 in H x 14.4 in W x 12 in D	286 mm H x 366 mm W x 305 mm D	175# 79.4Kg	CAB-26C
RL-60003	600	0.065	406	11.25 in H x 14.4 in W x 15 in D	286 mm H x 366 mm W x 381 mm D	270# 122.5Kg	CAB-26C
RL-75001	750	0.015	427	11.5 in H x 14.4 in W x 11 in D	292 mm H x 366 mm W x 279 mm D	140# 63.5Kg	CAB-26C
RL-75002	750	0.029	630	11.5 in H x 14.4 in W x 12.5 in D	292 mm H x 366 mm W x 318 mm D	190# 86.2Kg	CAB-26C
RL-75003	750	0.048	552	14.5 in H x 14.4 in W x 14 in D	368 mm H x 366 mm W x 356 mm D	265# 120.2Kg	CAB-26C
RL-85001B14	850	0.015	798	15.5 in H x 17.8 in W x 14.5 in D	394 mm H x 452 mm W x 368 mm D	195# 88.5Kg	CAB-26C
RL-85002B14	850	0.027	930	15.5 in H x 17.8 in W x 15.5 in D	394 mm H x 452 mm W x 394 mm D	215# 97.5Kg	CAB-26C
RL-85003B14	850	0.042	1133	15.5 in H x 17.8 in W x 17.5 in D	394 mm H x 452 mm W x 445 mm D	315# 142.9Kg	CAB-26D
RL-90001B14	900	0.013	860	16.8 in H x 17.8 in W x 13 in D	427 mm H x 452 mm W x 330 mm D	200# 90.7Kg	CAB-26D
RL-90002B14	900	0.025	1020	15.5 in H x 17.8 in W x 15.5 in D	394 mm H x 452 mm W x 394 mm D	215# 97.5Kg	CAB-26D
RL-90003B14	900	0.04	1365	15.8 in H x 17.8 in W x 17.1 in D	401 mm H x 452 mm W x 434 mm D	315# 142.9Kg	CAB-26D
RL-100001B14	1000	0.011	810	14.5 in H x 17.8 in W x 12.7 in D	368 mm H x 452 mm W x 323 mm D	144# 65.3Kg	CAB-26D
RL-100002B14	1000	0.022	1080	15.5 in H x 17.8 in W x 15.5 in D	394 mm H x 452 mm W x 394 mm D	215# 97.5Kg	CAB-26D
RL-100003B14	1000	0.038	1250	15.8 in H x 17.8 in W x 17.5 in D	401 mm H x 452 mm W x 445 mm D	315# 142.9Kg	CAB-26D
RL-120001B14	1200	0.009	870	15.5 in H x 17.8 in W x 14.5 in D	394 mm H x 452 mm W x 368 mm D	195# 88.5Kg	CAB-26D
RL-120002B14	1200	0.019	1270	15.5 in H x 17.8 in W x 17.8 in D	394 mm H x 452 mm W x 452 mm D	275# 124.7Kg	CAB-26D
RL-120003B14	1200	0.03	1530	15.4 in H x 17.4 in W x 18.3 in D	391 mm H x 442 mm W x 465 mm D	390# 176.9Kg	CAB-26D
RL-140001	1400	0.008	1235	17 in H x 22 in W x 22 in D	432 mm H x 559 mm W x 559 mm D	500# 226.8Kg	CAB-42C
RL-140002	1400	0.016	1523	17 in H x 19 in W x 19 in D	432 mm H x 483 mm W x 483 mm D	525# 238.1Kg	CAB-42C
RL-140003	1400	0.027	1680	17 in H x 22 in W x 22 in D	432 mm H x 559 mm W x 559 mm D	850# 385.6Kg	CAB-42C
RL-150001	1500	0.008	1432	17 in H x 22 in W x 22 in D	432 mm H x 559 mm W x 559 mm D	635# 288Kg	CAB-42C
RL-150002	1500	0.015	1671	17 in H x 16.9 in W x 16 in D	432 mm H x 429 mm W x 406 mm D	675# 306.2Kg	CAB-42C
RL-150003	1500	0.025	1815	17 in H x 22 in W x 22 in D	432 mm H x 559 mm W x 559 mm D	900# 408.2Kg	CAB-42C

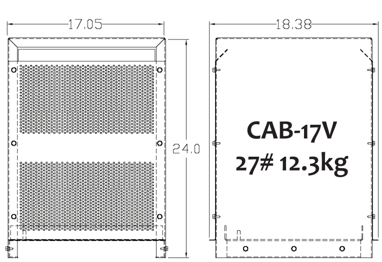
PRODUCT SELECTION: See MTE RL Selection Brochure or visit the MTE website at www.mtecorp.com and select the handy >> Reactor Click Find << for complete product selection & CAD files.

TERMINALS: Terminals are standard and save installation cost by minimizing panel space. Finger-proof (IP20) terminals are provided through 45 amps. Solid copper box lugs are provided above 45 amps to 160 amps. Copper tab type B14 or B1 flag terminals are used beyond 160 amps (see photo above).

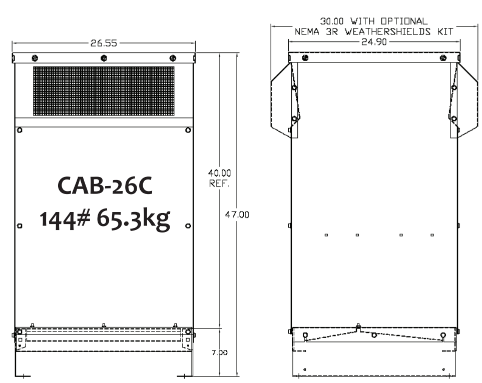
INSTALLATION OPTIONS: MTE line/load reactors are available in a variety of enclosures. The NEMA 1 for general protection or the NEMA 3R for weather protection.

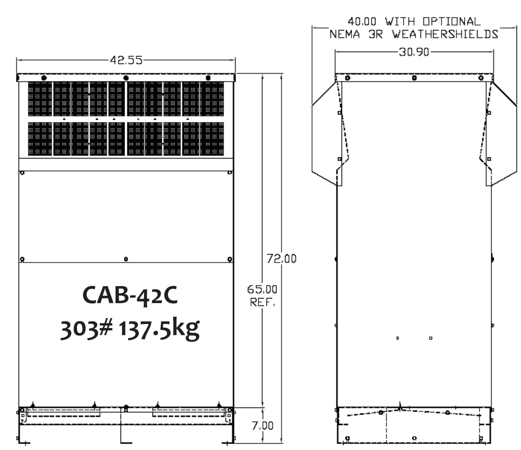
TRANSIENT PROTECTION OPTIONS: Various voltage rated MOV transient devices may be factory installed to reactor's output to offer the maximum over-voltage input drive security .





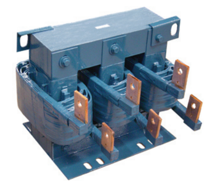
Note CAB-26D 72" H x 26.5"W x 24.9"D
CAB- 26D weight is 220# 99.8kg

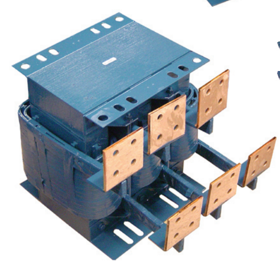


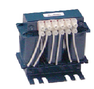


Product Specifications - RL Three Phase Reactors

Refer to the RL Line /Load Reactor User Manual for Detailed Specifications







Standard impedance values by calculation:	1.5%, 2, 3%, 4%, 5% available
Impedance basis	Reactor rated current, line voltage, frequency and inductance
Service Factor *(continuous)*	***Note: Select reactor based on rated current only***
Reactors rated 1 to 750 Amps	150% of rating
Reactors rated above 750 Amps	125% of rated minimum
Overload rating	200% of rated for 30 minutes 300% of rated for 1 minute
Maximum system voltage	600 Volts (units with terminal blocks) 690 Volts (units with box lugs or tab terminals)
Maximum switching frequency	20 KHz
Insulation system	Class N (**200°C** *392°F*)
Temperature rise *(open or enclosed reactors)*	**135°C** *275°F* (maximum)
Ambient temperature *(open or enclosed reactors)*	**45°C** *113°F* (Full rated)
Altitude *(maximum)*	1000 meters
Fundamental frequency *(Line or Load)*	50/60 Hz
Approvals:	CE, UL-508, CSA C22.2
Inductance curve *(typical)*	100% at 100% current 100% at 150% current 50% at 350% current (minimum)
Inductance tolerance	+/- 10%
Impregnation:	High Bond Strength "Solvent-Less" Epoxy, 200° C UL94HB recognized
Dielectric Strength	3000 volts rms (4243 volts peak)
dV/dT Protection	Meets NEMA MG-1, part 31 (same as inverter duty motors)
AGENCY APPROVALS:	
UL-508	File E180243 Component Listed (1 amp – 2400 amps)
UL-508	File E180243 **UL Listed** NEMA 1 units (1 amp – 2400 amps)

Note: Short Circuit rating not required under Exception No.1 of UL508A SB4.2.1 effective 4/25/06

CSA C22.2	File LR29753-13 CSA Certified (1 amp – 2400 amps)
Class N, 200° C	File E66214, Type 200-18, UL Recognized Insulation System
CE	Marked
MATERIAL:	
Core Steel:	Electrical grade high frequency silicon steel
Windings:	High dielectric withstand solid copper conductor (220° C)
Enclosures:	Sheet steel per UL and CSA requirements. Painted ANSI-61 Grey
Brackets:	ASTM structural steel or structural aluminum
Sheet Insulation:	DuPont Nomex 410 (220° C)
Epoxy:	Ripley Resin Type 468-2 (220° C)
CONSTRUCTION:	
CORE:	Electrical grade silicon steel magnetic laminations.
WINDINGS:	3000 volts rms dielectric strength (coil-to-coil & coil-to-core).
ASSEMBLY:	Windings are assembled onto EI laminations, secured in place & epoxy impregnated for minimum noise & maximum structural rigidity.
COLOR:	Royal Blue
TESTING:	Inductance, Hi-Pot 3000 Volts rms (5656 volts peak)

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Form 1185-2D-08

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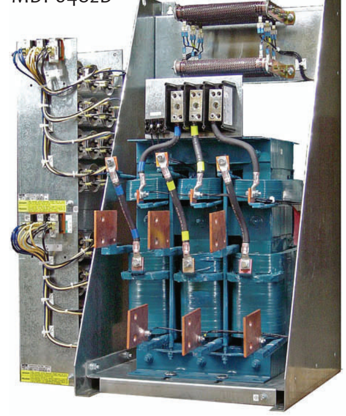
Matrix® Harmonic Filters

Series D - Selection Table & Technical Specifications Guide

IEEE-519 - The Series D Matrix® Harmonics Filter uses patented Harmonics Mitigating Reactor (HMR) technology to limit full load current distortion to less than 5% THID on virtually any kind of six pulse rectifier supply. Six pulse rectifiers are commonly found in three phase electronic equipment such as adjustable speed motor drives, welders, battery chargers, servo drives and other electronic equipment. Matrix® Filters enable your system to meet the voltage and current distortion limits of IEEE-519, EN61000, AS2279 and G5/4.

Reliability - Harmonic currents reduce equipment life, electrical system reliability, system efficiency and equipment productivity. Matrix® Filters reduce the burden on electrical equipment by reducing TRUE RMS current, peak current and harmonic frequency distortion. The series impedance included in the Matrix® Filter also absorbs transient over-voltages just like a line reactor, to prevent over-voltage trips and rectifier damage. Matrix® Filters also reduce the TRUE RMS current that flows through equipment feeding non-linear loads. This reduces the amount of heat generated by upstream equipment (such as transformers, disconnects, fuses, circuit breakers and conductors), extending their life expectancy. Increased system reliability leads to higher productivity for your overall system.

MDP0482D



Performance, Guaranteed! - Matrix® Harmonic Filters can meet or exceed the harmonic mitigation performance of other common filtration methods. Unlike alternative solutions, Matrix® Filters come with a performance guarantee. The Series D Matrix® Filter allows users to achieve superior attenuation of harmonics when used with 6 pulse drives and will outperform techniques using 12-pulse or 18-pulse rectification methods. The new patented HMR (Harmonic Mitigating Reactor) optimizes the technology for smaller packaging requiring less floor or panel space than other filter schemes. On AC variable frequency, variable torque drive applications (fans & pumps), Matrix filters will meet the guaranteed maximum levels of THID (total harmonic current distortion) at full load. Unlike other harmonic filter technologies, the performance of MTE Matrix Harmonic Filters is guaranteed!

Installation Options - Matrix Harmonic Filters are available in a variety of enclosure options. The standard enclosure meets the requirements of both Nema 1 & Nema 2. The Nema 3R enclosure provides weather protection and is available in optional stainless or galvanized steel construction. Optional Serpent/Rodent screens can be added to block small animals from entering enclosures.

For maximum flexibility, Matrix filters are also offered as open modular construction for integration into customer enclosures and panels.

MDG0103D

Electrical Options - Various contactor options may be added to provide for filter bypass and leading KVAR cancellation to enhance compatibility with standby power and support service requirements.

Typical Uses Include:

- Mission Critical Facilities
- AC Variable Frequency Drives
- DC Adjustable Speed Drives
- Electronic Welders
- Battery Chargers
- Fans and Pumps
- Water Treatment Facilities
- Induction Heating Equipment
- Elevator Drives
- Any 6 Pulse Rectifier Supply

The Matrix Filter is designed to be installed on the line side of a drive and deliver guaranteed IEEE-519 performance.

MTE Matrix® Filter Selection Tables

Selection Table **Series D Matrix® Harmonic Filter Technical Data - 208, 240, & 400VAC**

Note: replace "_" with P for open panel, "G" General NEMA 1-2 and "W" weather NEMA type 3R in Base part number

208 60hz	240 60hz	Base Part Number	Amps rating	Watts	Open Weight Lbs	Combined Magnetics Size	HMR Ref. Figure	Capacitor assembly size Inches	Capacitor Ref. Figure	Cab Type
1hp	1.5hp	**MD_0006A**	6	99	38	consult factory	Fig 2	consult factory	Fig 3	CAB-12C
2hp	2hp	**MD_0008A**	8	121	40	consult factory	Fig 2	consult factory	Fig 3	CAB-12C
3hp	3hp	**MD_0011A**	11	144	45	consult factory	Fig 2	consult factory	Fig 3	CAB-12C
		MD_0014A	14	169	45	consult factory	Fig 2	consult factory	Fig 3	CAB-12C
5hp	5hp	**MD_0021A**	21	214	60	consult factory	Fig 2	consult factory	Fig 3	CAB-12C
7.5hp	7.5hp	**MD_0027A**	27	254	65	consult factory	Fig 2	consult factory	Fig 3	CAB-12C
10hp	10hp	**MD_0034A**	34	286	85	consult factory	Fig 2	consult factory	Fig 3	CAB-12C
	15hp	**MD_0044A**	44	338	85	consult factory	Fig 2	consult factory	Fig 3	CAB-12C
15hp		**MD_0052A**	52	373	135	consult factory	Fig 2	consult factory	Fig 3	CAB-17C
20hp	20hp	**MD_0066A**	66	439	155	consult factory	Fig 2	consult factory	Fig 3	CAB-17C
25hp	30hp	**MD_0083A**	83	506	250	consult factory	Fig 2	consult factory	Fig 3	CAB-17C
30hp		**MD_0103A**	103	591	250	consult factory	Fig 2	consult factory	Fig 3	CAB-17C
40hp	40hp	**MD_0128A**	128	664	275	consult factory	Fig 2	consult factory	Fig 3	CAB-26C
50hp	60hp	**MD_0165A**	165	763	325	consult factory	Fig 2	consult factory	Fig 3	CAB-26C
60hp	75hp	**MD_0208A**	208	905	325	consult factory	Fig 2	consult factory	Fig 3	CAB-26C
75hp		**MD_0240A**	240	997	400	consult factory	Fig 2	consult factory	Fig 3	CAB-26C

Refer to Page 4 for Figures, Cabinet information, and Option details

Matrix® Filters for **Variable Torque AC Drives** rated 7.5 Hp and above should be selected for a filter output current rating greater than or equal to the motor current rating. If the motor current rating is not available, use the NEC motor current rating. AC drives rated 2 – 5 Hp should be selected for a filter output current rating greater than or equal to 105% of the motor current rating. If the motor current rating is not available, select on the basis of 105% of the NEC motor current rating. For those AC drives rated less than 1.5 Hp selection should be based on an output current rating greater than or equal to 110% of the motor current rating or 110% of the NEC motor current rating.

For **Constant Torque AC and DC Drive** applications operating from six pulse rectifier front ends, select a filter current rating according to application engineering note "Matrix Filter Operation in Constant Torque Applications with Six Pulse Rectifiers" or consult MTE engineering. For phase controlled DC drive applications, select filter current rating per application note "Matrix Filter with Phase Controlled DC Driver."

The **Capacitor Contactor Option** is recommended for generator applications where the kVA rating of the generator is less than 1.20 times the kVA rating of the Matrix® Filter. Calculate the kVA rating of the Matrix® Filter based on the input voltage rating and the output current rating. Contactor is sized to the filter capacitor current as listed in the user manual.

Where a single Matrix® Filter is used to feed multiple drives, the output current rating of the filter should be selected to equal the total current rating of the individual drives when calculated according to the instructions above.

400 50hz	Base Part Number	Amps rating	Watts	Open Weight Lbs	Open Magnetics Size	HMR Ref. Figure	Open Capacitor assembly size	Cap PNL Ref. Figure	Cab Type
1.5KW	**MD_0006C**	6	132	22	11.3"H x 6"W x 6.2"D	Fig 2	4.8"H x 4.8"W x 7.3"D	Fig 3	CAB-12C
2.2KW	**MD_0008C**	8	161	24	11.3"H x 6"W x 6.3"D	Fig 2	4.8"H x 4.8"W x 8.2"D	Fig 3	CAB-12C
3.7KW	**MD_0011C**	11	197	29	12.4"H x 7.2"W x 5.7"D	Fig 2	5.6"H x 5.6"W x 7.3"D	Fig 3	CAB-12C
5.5KW	**MD_0014C**	14	232	35	12.4"H x 7.3"W x 6.3"D	Fig 2	5.6"H x 5.6"W x 7.3"D	Fig 3	CAB-12C
7.5KW	**MD_0021C**	21	294	46	15.8"H x 9"W x 6.5"D	Fig 2	5.6"H x 5.6"W x 6.3"D	Fig 3	CAB-12C
11KW	**MD_0027C**	27	343	61	15.8"H x 9"W x 7"D	Fig 2	5.6"H x 5.6"W x 7.3"D	Fig 3	CAB-12C
15KW	**MD_0034C**	34	399	72	15.8"H x 9"W x 7.5"D	Fig 2	5.6"H x 5.6"W x 7.3"D	Fig 3	CAB-12C
18.5KW	**MD_0044C**	44	472	84	15.8"H x 9"W x 8"D	Fig 2	5.6"H x 5.6"W x 7.3"D	Fig 3	CAB-12C
22KW	**MD_0052C**	52	533	125	16.5"H x 12.3"W x 9.6"D	Fig 2	5.6"H x 5.6"W x 8.2"D	Fig 3	CAB-17C
30KW	**MD_0066C**	66	621	150	16.5"H x 12.3"W x 10.7"D	Fig 2	5.6"H x 5.6"W x 8.2"D	Fig 3	CAB-17C
37.5KW	**MD_0083C**	83	735	176	16.5"H x 12.3"W x 11.3"D	Fig 2	8"H x 7.3"W x 12"D	Fig 3	CAB-17C
45KW	**MD_0103C**	103	844	180	16.5"H x 12.3"W x 11"D	Fig 2	8"H x 8.1"W x 12"D	Fig 3	CAB-17C
55KW	**MD_0128C**	128	959	213	23"H x 15.3"W x 11.3"D	Fig 2	8"H x 9.1"W x 12"D	Fig 3	CAB-26C
75KW	**MD_0165C**	165	1143	278	23"H x 15.3"W x 11.5"D	Fig 2	12"H x 8.1"W x 12"D	Fig 3	CAB-26C
93KW	**MD_0208C**	208	1355	289	23"H x 15.3"W x 12"D	Fig 2	12"H x 9.1"W x 12"D	Fig 3	CAB-26C
112KW	**MD_0240C**	240	1493	298	23"H x 15.3"W x 12.4"D	Fig 2	15"H x 8.1"W x 12"D	Fig 3	CAB-26C
150KW	**MD_0320C**	320	1829	460	35.5"H x 18"W x 20.2"D	Fig 2	15"H x 8.1"W x 12"D 5.6"H x 5.6"W x 9.3"D	Fig 3 Fig 3	CAB-26D
225KW	**MD_0403C**	403	2098	504	35.5"H x 18"W x 22.5"D	Fig 2	15"H x 8.1"W x 12"D 8"H x 9.1"W x 12"D	Fig 3 Fig 3	CAB-26D
262KW	**MD_0482C**	482	2371	598	35.5"H x 18"W x 23"D	Fig 2	15"H x 9.1"W x 12"D 12"H x 9.1"W x 12"D	Fig 3 Fig 3	CAB-26D
300KW	**MD_0636C**	636	2929	866	35.5"H x 24"W x 23.5"D	Fig 2	15"H x 9.1"W x 12"D 15"H x 9.1"W x 12"D 5.6"H x 5.6"W x 8.2"D	Fig 3 Fig 3 Fig 3	CAB-30D
375KW	**MD_0786C**	786	3402	1087	35.5"H x 24"W x 24"D	Fig 2	15"H x 9.1"W x 12"D 12"H x 9.1"W x 12"D	Fig 3 Fig 3	CAB-30D

Selection Table Series D Matrix® Harmonic Filter Technical Data - 480 & 600VAC

Note: replace "_" with P for open panel, "G" General NEMA 1-2 and "W" weather NEMA type 3R in Base part number

480 60hz	Base Part Number	Amps rating	Watts	Open Weight Lbs	Open Magnetics Size	HMR Ref. Figure	Open Capacitor assembly size	Cap PNL Ref. Figure	Cab Type
3hp	MD_0006D	6	132	22	11.3"H x 6"W x 6.2"D	Fig 2	4.8"H x 4.8"W x 7.3"D	Fig 3	CAB-12C
5hp	MD_0008D	8	161	24	11.3"H x 6"W x 6.3"D	Fig 2	4.8"H x 4.8"W x 7.3"D	Fig 3	CAB-12C
7.5hp	MD_0011D	11	197	29	12.4"H x 7.2"W x 5.7"D	Fig 2	4.8"H x 4.8"W x 8.2"D	Fig 3	CAB-12C
10hp	MD_0014D	14	232	35	12.4"H x 7.3"W x 6.3"D	Fig 2	4.8"H x 4.8"W x 8.2"D	Fig 3	CAB-12C
15hp	MD_0021D	21	294	46	15.8"H x 9"W x 6.5"D	Fig 2	5.6"H x 5.6"W x 7.3"D	Fig 3	CAB-12C
20hp	MD_0027D	27	343	61	15.8"H x 9"W x 7"D	Fig 2	5.6"H x 5.6"W x 8.2"D	Fig 3	CAB-12C
25hp	MD_0034D	34	399	72	15.8"H x 9"W x 7.5"D	Fig 2	5.6"H x 5.6"W x 8.7"D	Fig 3	CAB-12C
30hp	MD_0044D	44	472	84	15.8"H x 9"W x 8"D	Fig 2	5.6"H x 5.6"W x 7.3"D	Fig 3	CAB-12C
40hp	MD_0052D	52	533	125	16.5"H x 12.3"W x 9.6"D	Fig 2	5.6"H x 5.6"W x 7.3"D	Fig 3	CAB-17C
50hp	MD_0066D	66	621	154	16.5"H x 12.3"W x 10.7"D	Fig 2	8"H x 7.3"W x 12"D	Fig 3	CAB-17C
60hp	MD_0083D	83	735	176	16.5"H x 12.3"W x 11.3"D	Fig 2	8"H x 7.3"W x 12"D	Fig 3	CAB-17C
75hp	MD_0103D	103	844	180	16.5"H x 12.3"W x 11"D	Fig 2	8"H x 7.3"W x 12"D	Fig 3	CAB-17C
100hp	MD_0128D	128	959	217	23"H x 15.3"W x 11.3"D	Fig 2	12"H x 7.3"W x 12"D	Fig 3	CAB-26C
125hp	MD_0165D	165	1143	273	23"H x 15.3"W x 11.5"D	Fig 2	12"H x 7.3"W x 12"D	Fig 3	CAB-26C
150hp	MD_0208D	208	1355	292	23"H x 15.3"W x 12"D	Fig 2	15"H x 7.3"W x 12"D	Fig 3	CAB-26C
200hp	MD_0240D	240	1493	298	23"H x 15.3"W x 12.4"D	Fig 2	15"H x 7.3"W x 12"D	Fig 3	CAB-26C
250hp	MD_0320D	320	1829	464	35.5"H x 18"W x 20.2"D	Fig 2	15"H x 7.3"W x 12"D 8"H x 7.3"W x 12"D	Fig 3 Fig 3	CAB-26D
300hp	MD_0403D	403	2098	508	35.5"H x 18"W x 22.5"D	Fig 2	12"H x 7.3"W x 12"D 15"H x 7.3"W x 12"D	Fig 3 Fig 3	CAB-26D
400hp	MD_0482D	482	2371	602	35.5"H x 18"W x 23"D	Fig 2	15"H x 7.3"W x 12"D 15"H x 7.3"W x 12"D	Fig 3 Fig 3	CAB-26D
500hp	MD_0636D	636	2929	873	35.5"H x 24"W x 23.5"D	Fig 2	12"H x 8.1"W x 12"D 15"H x 7.3"W x 12"D 15"H x 7.3"W x 12"D	Fig 3 Fig 3 Fig 3	CAB-30D
600hp	MD_0786D	786	3402	1082	35.5"H x 24"W x 24"D	Fig 2	15"H x 7.3"W x 12"D 15"H x 7.3"W x 12"D 15"H x 7.3"W x 12"D 5.6"H x 5.6"W x 7.3"D	Fig 3 Fig 3 Fig 3 Fig 3	CAB-30D
700hp	MD_0850D	850	3750	1163					CAB-48D
800hp	MD_0980D	980	4150	1346					CAB-48D
900hp	MD_1050D	1050	4527	1444					CAB-48D
1000hp	MD_1200D	1200	5107	1656					CAB-48D

600 60hz	Base Part Number	Amps rating	Watts	Open Weight Lbs	Open Magnetics Size	HMR Ref. Figure	Open Capacitor assembly size	Cap PNL Ref. Figure	Cab Type
5hp	MD_0006E	6	142	18	11.3"H x 6"W x 6.2"D	Fig 2	5.6"H x 5.6"W x 9.3"D	Fig. 3	CAB-12C
	MD_0008E	8	173	20	12.3"H x 7.3"W x 5.8"D	Fig 2	5.6"H x 5.6"W x 9.3"D	Fig. 3	CAB-12C
10hp	MD_0011E	11	215	25	12.3"H x 7.3"W x 6.1"D	Fig 2	5.6"H x 5.6"W x 7.3"D	Fig. 3	CAB-12C
	MD_0014E	14	253	32	15.8"H x 9"W x 6.5"D	Fig 2	5.6"H x 5.6"W x 8.2"D	Fig. 3	CAB-12C
15hp	MD_0021E	21	328	42	15.8"H x 9"W x 7"D	Fig 2	5.6"H x 5.6"W x 9.3"D	Fig. 3	CAB-12C
25hp	MD_0027E	27	387	59	15.8"H x 9"W x 7.5"D	Fig 2	5.6"H x 5.6"W x 7.3"D	Fig. 3	CAB-12C
30hp	MD_0034E	34	449	70	15.8"H x 9"W x 8"D	Fig 2	5.6"H x 5.6"W x 8.2"D	Fig. 3	CAB-12C
40hp	MD_0044E	44	542	80	16.5"H x 12.3"W x 9.4"D	Fig 2	8"H x 9.1"W x 12"D	Fig. 3	CAB-12C
50hp	MD_0052E	52	611	124	16.5"H x 12.3"W x 10.4"D	Fig 2	8"H x 9.1"W x 12"D	Fig. 3	CAB-17C
60hp	MD_0066E	66	718	149	16.5"H x 12.3"W x 11.3"D	Fig 2	8"H x 9.1"W x 12"D	Fig. 3	CAB-17C
75hp	MD_0083E	83	843	173	16.5"H x 12.3"W x 11.6"D	Fig 2	12"H x 9.1"W x 12"D	Fig. 3	CAB-26C
100hp	MD_0103E	103	977	178	22.9"H x 15.5"W x 11.5"D	Fig 2	12"H x 9.1"W x 12"D	Fig. 3	CAB-26C
125hp	MD_0128E	128	1136	210	22.9"H x 15.5"W x 11.9"D	Fig 2	15"H x 9.1"W x 12"D	Fig. 3	CAB-26C
150hp	MD_0165E	165	1349	289	27.4"H x 15.5"W x 13.4"D	Fig 2	15"H x 9.1"W x 12"D	Fig. 3	CAB-26C
200hp	MD_0208E	208	1614	278	27.4"H x 15.5"W x 12.3"D	Fig 2	15"H x 9.1"W x 12"D	Fig. 3	CAB-26C
250hp	MD_0240E	240	1821	296	35.5"H x 16.5"W x 24"D	Fig 2	15"H x 9.1"W x 12"D	Fig. 3	CAB-26D
300hp	MD_0320E	320	2184	453	35.5"H x 22.5"W x 24"D	Fig 2	15"H x 9.1"W x 12"D 5.6"H x 5.6"W x 9.3"D	Fig. 3 Fig. 3	CAB-26D
400hp	MD_0403E	403	2529	494	35.5"H x 22.5"W x 24"D	Fig 2	15"H x 9.1"W x 12"D 15"H x 9.1"W x 12"D	Fig. 3 Fig. 3	CAB-26D
500hp	MD_0482E	482	2915	583	35.5"H x 22.5"W x 24"D	Fig 2	15"H x 9.1"W x 12"D 12"H x 9.1"W x 12"D 12"H x 9.1"W x 12"D	Fig. 3 Fig. 3 Fig. 3	CAB-30D
600hp	MD_0636E	636	3621	834	35.5"H x 22.5"W x 25"D	Fig 2	8"H x 9.1"W x 12"D 12"H x 9.1"W x 12"D	Fig. 3 Fig. 3	CAB-30D
800hp	MD_0786E	786	4267	1072	35.5"H x 22.5"W x 25.3"D	Fig 2	15"H x 9.1"W x 12"D 15"H x 9.1"W x 12"D 8"H x 9.1"W x 12"D	Fig. 3 Fig. 3 Fig. 3	CAB-42D

Enclosure & Electrical Options **Series D Matrix® Harmonic Filters**

Type	Size inches	3R Depth	Weight
CAB-12C	24"H x 13"W x 18"D	23"	74#
CAB-17C	31"H x 18"W x 21"D	26"	96#
CAB-26C	47"H x 27"W x 25"D	30"	180#
CAB-26D	72"H x 27"W x 25"D	35"	256#
CAB-30D	82"H x 31"W x 32"D	40"	319#
CAB-42D	82"H x 43"W x 31"D	40"	393#
CAB-48D	82"H x 49"W x 37"D	46"	518#

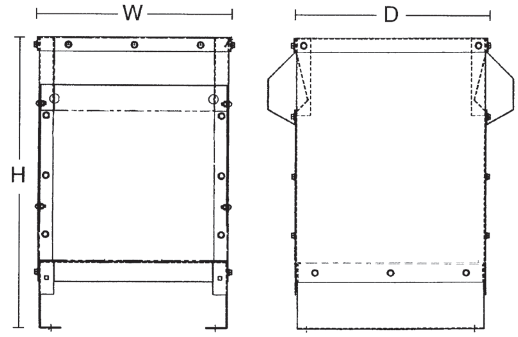


Figure 1 - General Purpose Enclosure
NEMA 1, 2, & 3R

Enclosure Options - Series D Matrix® Harmonic Filters

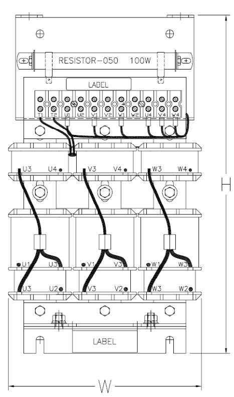
***Option -100* - NEMA 3R enclosure with high endurance white paint:** These galvanized enclosures are supplied with continuous welds on the top cover and weather shields. Exterior hardware is supplied with gaskets.

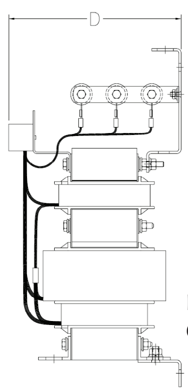
***Option -200* - NEMA 3R STAINLESS STEEL enclosure with high endurance white paint:** These enclosures are constructed from 316L stainless alloy using stainless steel hardware. Gaskets are applied to weather proof exterior components. The exterior surfaces of the enclosure are finished in high endurance white polyester powder coat.

***Option -300* - Standard Grey enclosure with optional Serpent/Rodent screens:** Provides intake exhaust air screens with (¼in X ¼in) mesh openings.

***Option -400* - NEMA 3R enclosure with high endurance white paint plus Serpent/Rodent screens:** This option incorporates air intake screens with ¼in X ¼in mesh openings with the white painted NEMA 3R enclosure of Option -100.

***Option -500* - NEMA 3R STAINLESS STEEL enclosure with high endurance white paint plus Serpent/Rodent screens:** This option incorporates air intake screens with ¼in X ¼in mesh openings with the white painted NEMA 3R enclosure of Option -200.





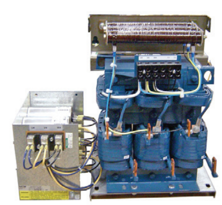
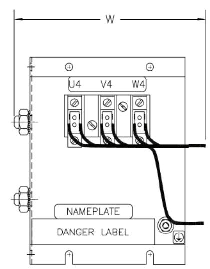
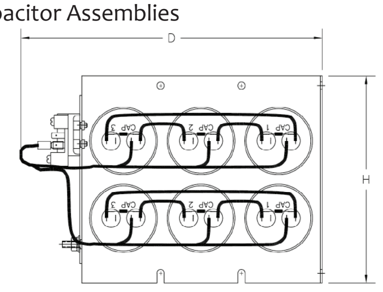


Figure 2 -
Open Magnetics

Figure 3 -
Capacitor Assemblies





Electrical Options - Series D Matrix® Harmonic Filters

***Option -002* - Capacitor Contactor:** This option provides a contactor to disconnect the filter capacitor bank (KVAR current becomes zero) when the drive is not running. The contactor is supplied with NO/NC auxiliary contacts. The contactor coil and auxiliary contacts are wired to a customer terminal block. A 120Volt 60Hz power source is required for this option.
Option -012 is a self powered version.

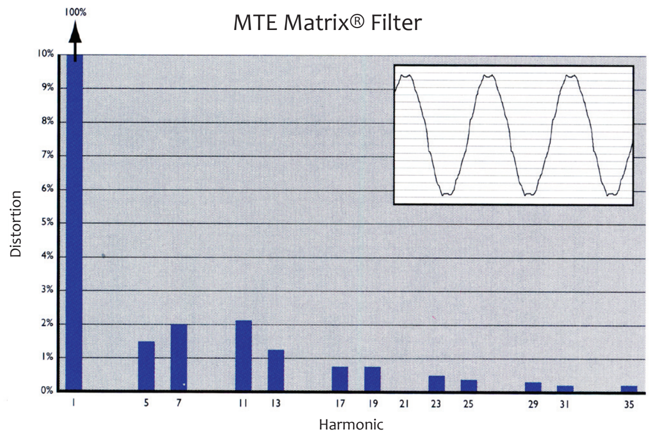
***Option -009* - Capacitor Contactor with adjustable pick-up and drop-out:** This option provides a contactor to disconnect the filter capacitor bank based on the motor load current. Two current operated switches provide independent adjustment of the pick-up and drop-out current levels. The switches are preset at the factory for pick-up at 50% and drop-out at 20% of the filter output current rating. The switches are field adjustable over a 0% to 100% current range. This option includes a 120VAC control transformer.

***Option -010* - Filter Bypass:** The filter bypass option is designed to provide filter bypass for drives that have an integrated bypass option as typically found in HVAC applications. Filter bypass is initiated by a contact closure when the motor is switched to operate directly from the AC line instead of the drive. A 120VAC control power source is required.
Option -011 is a self powered version.

***Option -013* - Filter bypass and capacitor contactor with control transformer:** This option combines the filter bypass (*Option -010*) with a self-powered customer controlled capacitor disconnect contactor (*Option -012*). A jumper selection provides single contact switching for normal bypass control with capacitor removal.

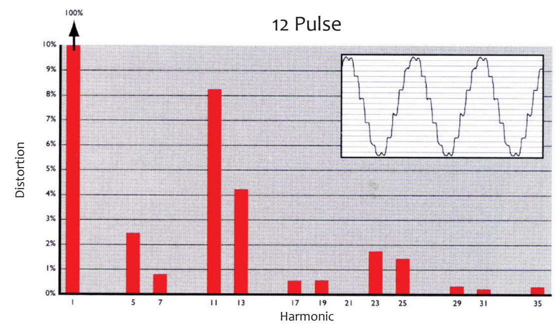
See the Matrix® Filter difference for yourself!

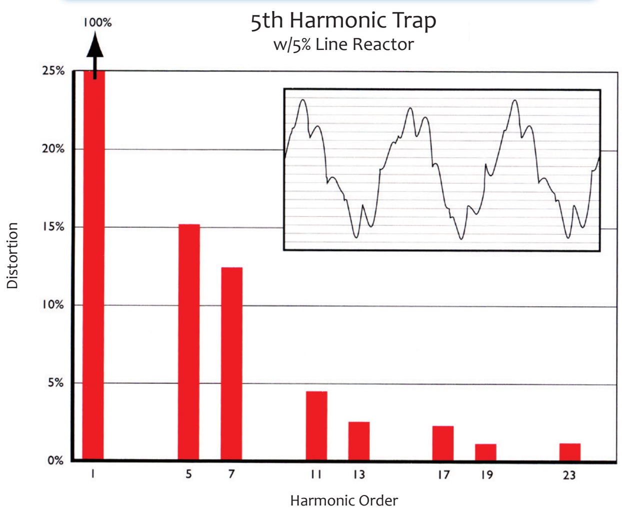
Compare the difference in waveform and harmonic spectrum for real life tests performed at full load conditions for various harmonic mitigation techniques.

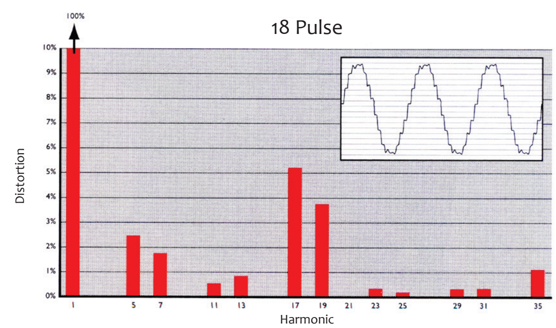


IEEE-519 Current Distortion Limits	
Isc/IL	**Total Demand Distortion (TDD)**
< 20	**5%**
20 < 50	**8%**
50 < 100	**12%**
100 <1000	**15%**
> 1000	**20%**

Matrix® Filters attenuate harmonics better than these alternative filtering techniques. Data based on actual tests at full load power.







Part Number Code: MD X _ _ _ _ X _ _ _

Product Code Matrix Series D

Type

P Panel Mnt G General Purpose NEMA2 W Weather NEMA3R

Current Rating

0006 6 amps 0786 786 amps

Voltage Frequency Code

C 380VAC - 415VAC 50Hz D 480VAC 60Hz

Enclosure Options

Contactor Options

Product Specifications - Matrix® Harmonic Filters

Refer to the MTE SERIES D MATRIX® HARMONIC FILTER User Manual for Detailed Specifications

Matrix Filters are designed to operate and will achieve guaranteed performance under the follow conditions:

Load: 6 pulse rectifier, operating in variable torque mode and chosen from the standard selection table. For constant torque application select filter rating based on appropriate application note: **AN-0106**

Input voltage:	Nominal voltage VAC +/- 10%, 3 Phase
Frequency:	Nominal Frequency + .75 Hz
Input voltage line unbalance:	1% maximum
Maximum source impedance:	6.00%
Minimum source impedance:	1.5%
Service Factor:	1.00

Ambient Temperature (Operating)

Enclosed Filters:	-40 to +40 degrees C
Open Panel Filters:	-40 to +50 degrees C
Storage Temperature:	-40 to +90 degrees C

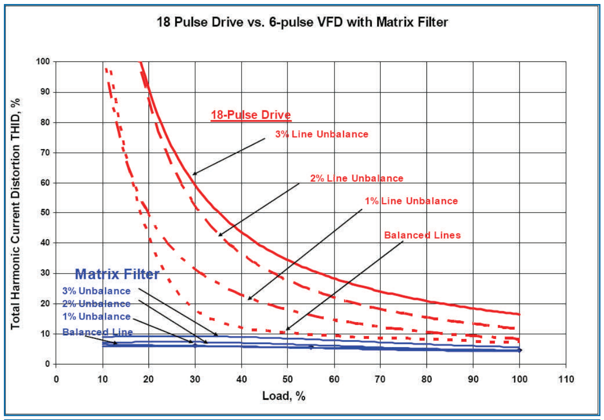
Altitude:	0 to 3300 Feet above sea level without derating
Relative Humidity:	0 to 95% non-condensing

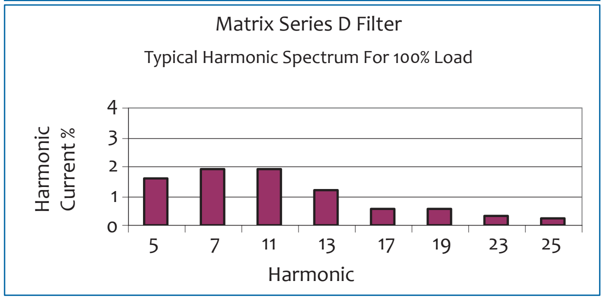
Agency Approvals

UL and cUL listed : UL508 and CSA-C22.2 No 14-95 File E180243 (3HP to 1000HP, 120VAC to 600VAC, 50Hz, 50/60Hz, & 60Hz Three Phase)

Performance

Total Harmonic Current Distortion: 5% MAX at FULL LOAD





Performance Guarantee

Select & install the appropriate Matrix Harmonic Filter in a variable torque AC variable frequency drive application, within our published system limits & we guarantee that the input current distortion will be less than or equal to 5% THID for MD Series filters at full load. If a properly sized & installed filter fails to meet its specified THID level, MTE will provide the necessary modifications or replacement filter at no charge. TDD will typically be even lower than THID.

Matrix filters can also provide similar performance in other drive applications such as constant torque, DC drives & other phase controlled rectifiers, but actual THID levels can vary by load and/or speed & therefore cannot be guaranteed. Consult factory for assistance when applying Matrix filters on these types of equipment

MINIMUM SYSTEM REQUIREMENTS:

The guaranteed performance levels of this filter will be achieved when the following system conditions are met:

Source impedance:	1.5% minimum to 6.0% max
Frequency:	60Hz ± 0.75Hz
System Voltage:	Nominal System Voltage (line to line) ±10%
Balanced Line Voltage:	within 1%,
Background Voltage Distortion:	0% THVD.

NOTE: The presence of background voltage distortion will cause motors & other linear loads to draw harmonic currents. Additional harmonic currents may flow into the Matrix filter if there is harmonic voltage distortion already on the system.

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Performance of Harmonic Mitigation Alternatives

MTE Corporation

Abstract: *Users of variable frequency drives often have strict demands placed on them to mitigate harmonic distortion caused by non-linear loads. Many choices are available to them including line reactors, harmonic traps, 12-pulse rectifiers, 18-pulse rectifiers, and low pass filters. Some of these solutions offer guaranteed results and have no adverse effect on the power system, while the performance of others is largely dependent on system conditions. Certain techniques require extensive system analysis to prevent resonance problems and capacitor failures, while others can be applied with virtually no analysis whatsoever. In some cases harmonic mitigation technique decisions were based on a technical misunderstanding, lack of information, theoretical data or on invalid assumptions.*

This paper explains the theory of operation of various passive harmonic mitigation techniques and demonstrates their typical real life performance. It takes the guesswork out of harmonic filtering by demonstrating the typical performance of various harmonic mitigation techniques and offering a quantitative analysis of alternatives for real life VFD operating conditions.

1 SOURCE REACTANCE

The magnitude of harmonic currents in an individual non-linear load depends greatly on the total effective input reactance, which is comprised of the source reactance plus added line reactance. Given a six pulse rectifier with dc bus capacitor, one can predict the resultant input current harmonic spectrum based on the input reactance. The lower the source reactance, (the more stiff the power source), the higher the harmonic content will be.

1.1 Typical Harmonic Performance

The typical harmonic spectrum data for a six-pulse rectifier load fed by a stiff power source (0.25% and 0.5% impedance) is as follows:

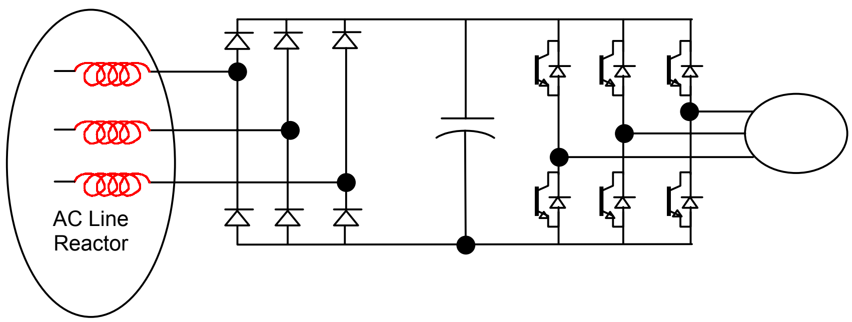
h	0.25% reactance	0.50% reactance
5th	102%	78%
7th	92%	58%
11th	26%	18%
13th	14%	10%
17th	10%	7%
19th	8.5%	6%
23rd	7%	5%
25th	3%	2.3%
THID	**141%**	**100%** **(THID = total harmonic current distortion)**

Since power distribution transformers frequently have impedance ratings between 1.5% and 5.75%, one would expect that source impedance is often relatively high and that harmonics should therefore be quite low. However, transformer impedance ratings are based on transformer rated KVA, so when the transformer is partially loaded, the effective impedance of the transformer, relative to the actual load, is proportionately lower, [ie: 1.5% impedance at 30% load = 0.5% effective impedance].

2 LINE REACTORS

The use of AC line reactors is a common and economical means of increasing the source impedance relative to an individual load. Line reactors are connected in series with the six pulse rectifier diodes at the input to the VFD, as shown in *Fig 1*.

Fig 1.



2.1 Typical Harmonic Performance of Reactors

The typical harmonic spectrum data for a six pulse VFD load fed by a power supply with an effective source reactance of 3%, 5% and 8% looks as follows:

h	**3 % reactance**	**5% reactance**	**8% impedance 3% dc choke & 5% ac reactor**
5th	39%	32%	27%
7th	17%	12%	9%
11th	7%	5.8%	4.5%
13th	5%	3.9%	3.2%
17th	3%	2.2%	1.8%
19th	2.2%	1.7%	1.4%
23rd	1.5%	1%	0.8%
25th	1%	0.9%	0.75%
THID	**44%**	**35%**	**29%**

These data represent the harmonics measured at the input to the six pulse rectifier and will reduce to lower percentages when measured further upstream, provided there are other linear loads operating on the system. If 20% of the system load is comprised of VFDs with 5% input impedance, and 80% has linear loads, the harmonic current distortion at the VFD input will be 35% THID, but only 7% at the supply transformer secondary. Typically costing less than 3% of the motor drive system, line reactors are the most economical means of reducing harmonics. Practical ratings can achieve 29% to 44% THID at the input to the six pulse rectifier (usually lower THID at the transformer secondary), at full load operation. Their typical watts losses are less than 1% of the load.

Fig. 2 illustrates the input current waveform of a six pulse rectifier supplied by a power source of (a) 0.5% effective impedance and (b) 3% effective impedance.

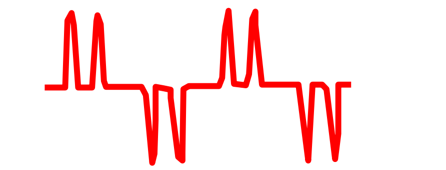


Fig. 2(a) Input Current waveform of 6-pulse rectifier w/0.5% impedance

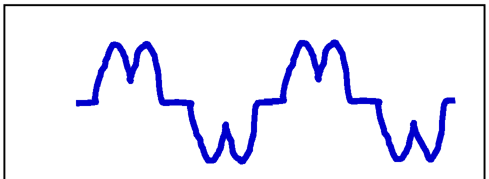
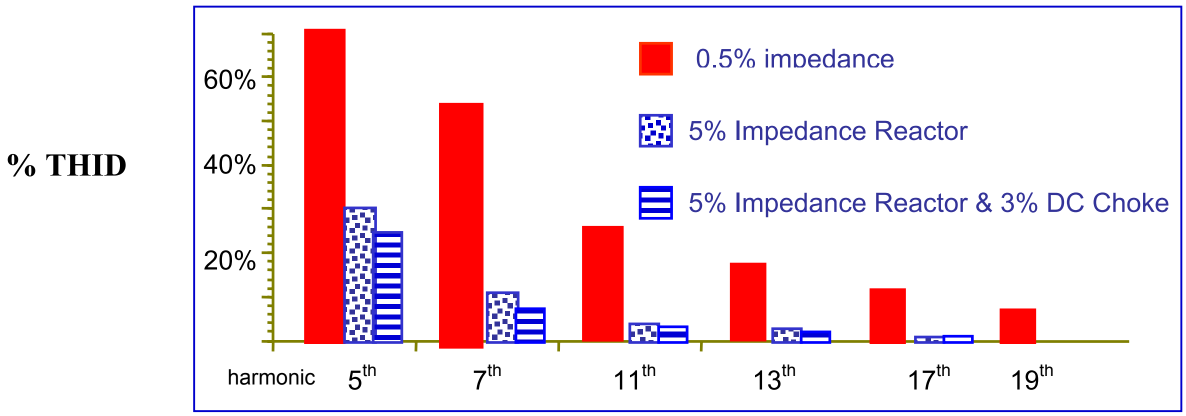


Fig. 2(b) Input current of 6-pulse rectifier w/ 3% impedance

Fig. 3 illustrates the typical harmonic spectrum for a six-pulse rectifier with 0.5%, 5% or 8% effective source impedance, (8% = 5% line reactor + 3% DC bus choke).



2.2 Reactor Performance at Light Load

The harmonic mitigation performance of reactors varies with load because their effective impedance reduces proportionately as the current through them is decreased. At full load, a 5% effective impedance reactor achieves harmonic distortion of 35% THID, however, at 60% load it's effective impedance is only 3% {0.6 x 5% = 3%}, and harmonics will be 44% THID. Although THID increased as a percentage, the total rms magnitude of harmonic current actually decreased by nearly 25% {1 – ((.6 x 44%) / 35%) = 24.5%}. Since voltage distortion at the transformer secondary is dependent upon the magnitude and frequency of current harmonics that cause harmonic voltage drops across the transformer's internal reactance, the voltage distortion (THVD), at the transformer secondary, actually decreases as this load is reduced.

3 TUNED HARMONIC TRAP FILTERS

3.1 Harmonic Trap Performance

Tuned harmonic filters (traps) involve the series connection of an inductance and capacitance to form a low impedance path for a specific (tuned) harmonic frequency. The filter is connected in parallel (shunt) with the power system to divert the tuned frequency currents away from the power source.

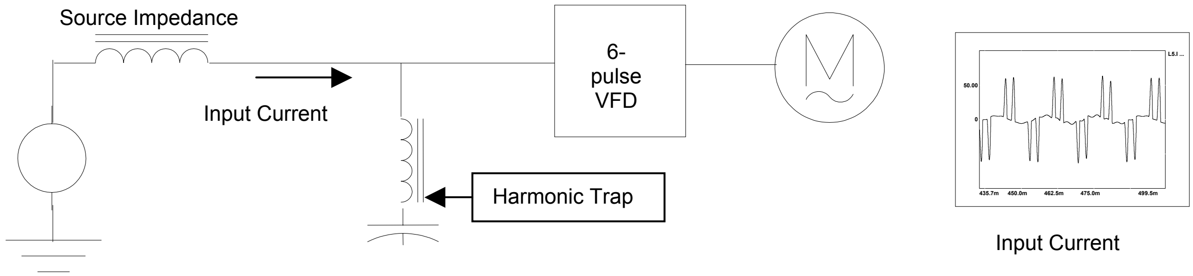


Fig. 4 (with 0.25% source impedance)

Unlike line reactors, harmonic traps do not attenuate all harmonic frequencies. Most often they are tuned for 5th harmonic mitigation. If applied to a low impedance power source, as demonstrated in *Fig. 4*, the harmonic mitigation performance of this filter is quite limited and the benefit of this filter may be unrecognizable. To improve the performance of a trap filter, a 5% impedance line reactor may be connected in series with the input to the filter, as shown in *Fig. 5*.

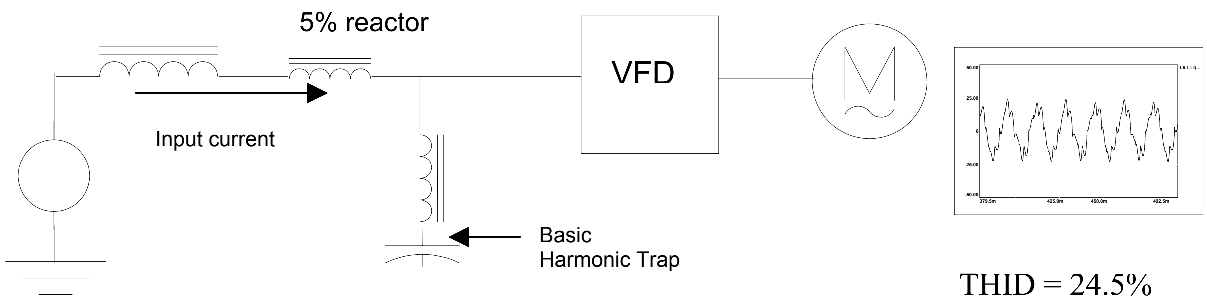


Fig. 5 (with 0.25% source impedance)

If the VFD has internal line reactance, then harmonic trap performance may improve slightly. The typical residual THID for a six pulse rectifier with a tuned 5th harmonic trap is between 20% to 30% at full load, provided there is significant source impedance. The watts loss of this type of filter can be 2-3% of the load and it can cost ten times the price of a line reactor. Tuned harmonic traps will alter the natural resonant frequency of the power system and may cause system resonance, increasing specific harmonic levels. They may attract harmonics from other non-linear loads sharing the same power source and must be increased in capacity to accommodate the addition of new loads. For best results, a power system study should be performed to determine the magnitude of harmonics to be filtered (from all loads), the power system resonant frequency and the impact of future addition of loads.

3.2 Harmonic Traps at Light Load Conditions

Harmonic traps achieve their best attenuation of harmonics at full load conditions. At light load, the resultant THID can increase significantly and may be no better than the performance normally achieved with a line reactor. *Fig. 6* demonstrates the input current waveform of a six pulse rectifier with a tuned 5th harmonic trap, operating at 50% load, when the line voltages were 3% unbalanced. Notice the similarity to a non-linear single phase load.

Fig. 6 Input current waveform for a Six-pulse rectifier with 5th harmonic tuned harmonic filter, measured at 50% load, and with 3% line voltage unbalance and 0.25% source impedance.

Harmonic current distortion = 139% THID

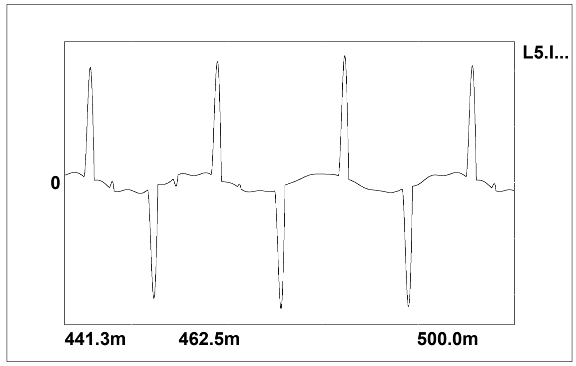


Fig. 6

4 12-PULSE RECTIFICATION

4.1 Theory of performance

Twelve pulse rectifier configurations have been used for applications demanding lower harmonic levels than can be achieved using either traps or reactors. The theoretical benefits of 12-pulse rectification include cancellation of 5th, 7th, 17th, 19th, etc harmonics. However, real life harmonic mitigation resulting from the use of twelve pulse rectifiers can be quite different than one's theoretical expectations. The most common method of twelve pulse rectification involves the parallel connection of two bridge rectifiers, each fed by a 30 degrees phase shifted transformer winding. Often the transformer has a single primary winding and dual secondary windings. One secondary winding is a delta and the other is connected in wye configuration to achieve 30 degrees of phase shift between secondary voltages.

"A major design goal in multipulse operation is to get the converters, or converter semiconductor devices, to share current equally. If this is achieved, then maximum power and minimum harmonic currents can be obtained."(1) In order to achieve cancellation of harmonics, the two individual bridge rectifiers must share current equally. This can only be achieved if the output voltage of both transformer secondary windings are exactly equal. "Because of differences in the transformer secondary impedances and open circuit output voltages, this can be practically accomplished for a given load (typically rated load) but not over a range in loads."(2) Typical losses of a twelve pulse transformer are 3% to 5% of the transformer KVA rating.

4.2 Twelve Pulse Performance with Balanced Line Voltages

Fig. 7 illustrates actual measurements of input current harmonic distortion for a twelve pulse rectifier supplied from a balanced three phase voltage source while operating at full load conditions. For test purposes, the transformer had a delta primary with delta and wye secondary windings (each rated at one-half line voltage). To obtain "best case" results, the bridge rectifiers were series connected so equal DC current flowed in each converter. The data shows that when the current through both sets of rectifiers is equal, harmonics can be as low as 10% to 12% THID at full load. Current sharing reactors will help parallel connected bridge rectifiers to share current equally. While current sharing reactors are highly recommended for twelve pulse configurations, they are usually omitted in the interest of minimizing cost. Even with balanced current however, harmonic distortion can increase appreciably at light load conditions.

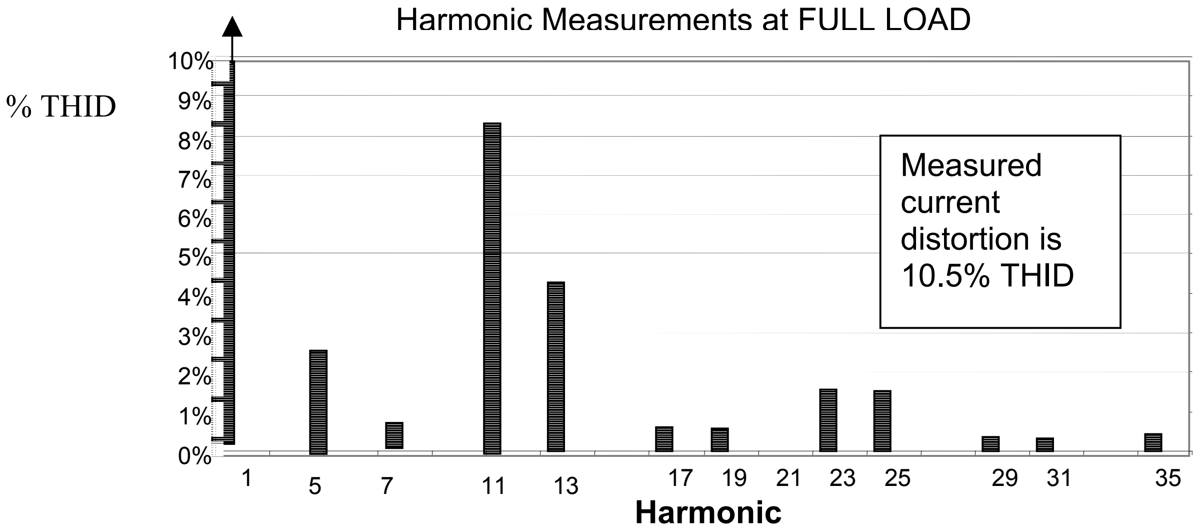
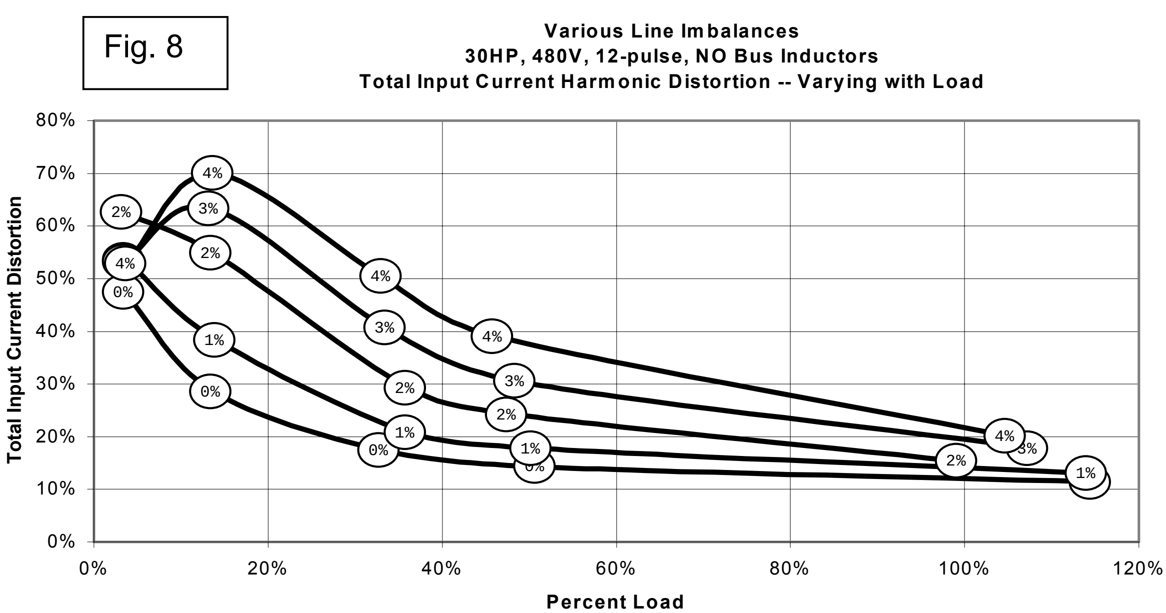


Fig. 7 Harmonic spectrum for 12-pulse rectifier, measured while *operating at full load*, when line voltages were balanced.

4.3 Twelve-Pulse Performance when Line Voltages are Not Balanced

Practical aspects of multipulse transformer winding configurations and circuit parameters make it unlikely that perfect balance can be achieved between all six secondary voltages, especially when the load is varied from *full load* to *no load* conditions. Additionally, facility power system voltage unbalance is common (according to ANSI C84.1, 34% of facilities surveyed in the USA experienced between 1% and 3% voltage unbalance at the service entrance point and even greater unbalance in the facility and closer to the loads). It is interesting to note that occasionally 12-pulse drives are sold without the transformer, shifting responsibility for the transformer specification and system performance from the supplier to the user or installer. *Fig. 8* demonstrates the impact of both line voltage unbalance and light loading conditions on the harmonic mitigation performance of twelve pulse rectifiers. Even with perfectly balanced line voltages, the resultant %THID increases as the load is reduced (ie: 23% THID at 20% load).

Fig. 8



5 EIGHTEEN PULSE RECTIFIERS

5.1 18-Pulse Rectifier Theory of Operation

Eighteen pulse configurations use a transformer with three sets of three phase outputs that are phase shifted by 20 degrees each, to supply three sets of full wave bridge rectifiers. Theoretically, this configuration cancels the 5^{th}, 7^{th}, 11^{th}, 13^{th}, 23^{rd}, 25^{th}, 29^{th}, 31^{st}, etc harmonics. One might imagine that it may be quite optimistic to expect the nine supply voltages, feeding three bridge rectifiers, to be exactly equal at all operating conditions. Maintaining equal DC current through three bridges seems more difficult than with twelve pulse systems simply because the number of variables increases by fifty percent. As with 12-pulse systems, the 18-pulse rectifier's ability to reduce harmonic currents is best when operating at full load conditions and when all of the nine voltages are equal.

5.2 18-Pulse Rectifier Performance at Full Load with Balanced Line Voltages

In a laboratory exercise it is possible to control the three line voltages that supply the 18-pulse transformer primary winding, however in real life applications this may be quite difficult to achieve. Even when the primary voltages are balanced, maximum attenuation of harmonics with 18-pulse rectifiers, requires that all nine secondary voltages be balanced. This allows DC current to be shared equally by each of the three bridge rectifiers, provided the semiconductor and circuit resistances are identical for all phases. Due to the large number of variables, the likelihood of achieving theoretical harmonic performance is rather poor. *Fig. 9* demonstrates the harmonic current spectrum measurement for an 18-pulse rectifier, operating at full load, with the three primary voltages balanced. To demonstrate the best case scenario, the three bridge rectifiers were connected in series to assure equal sharing of DC current.

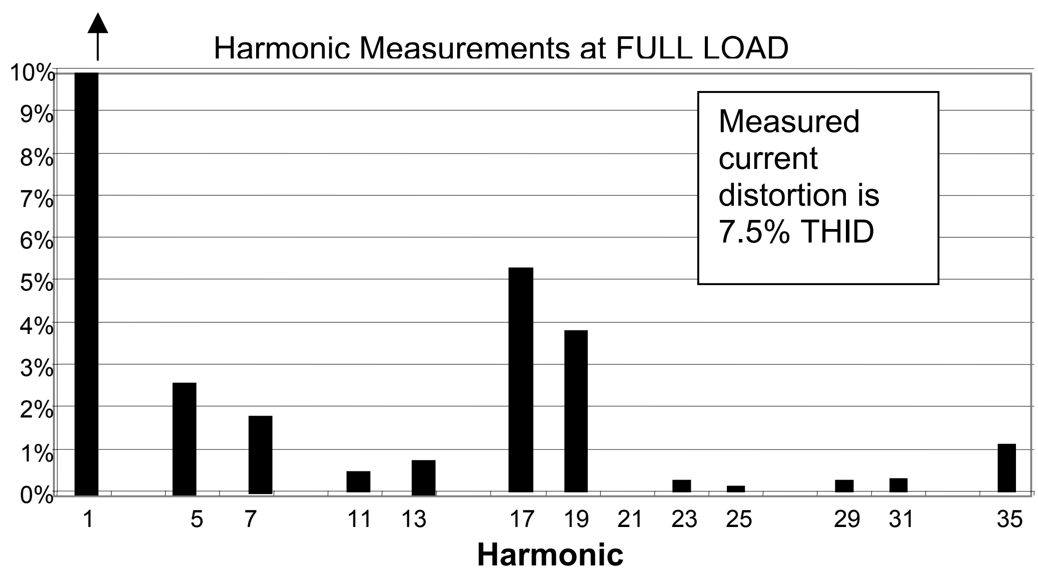


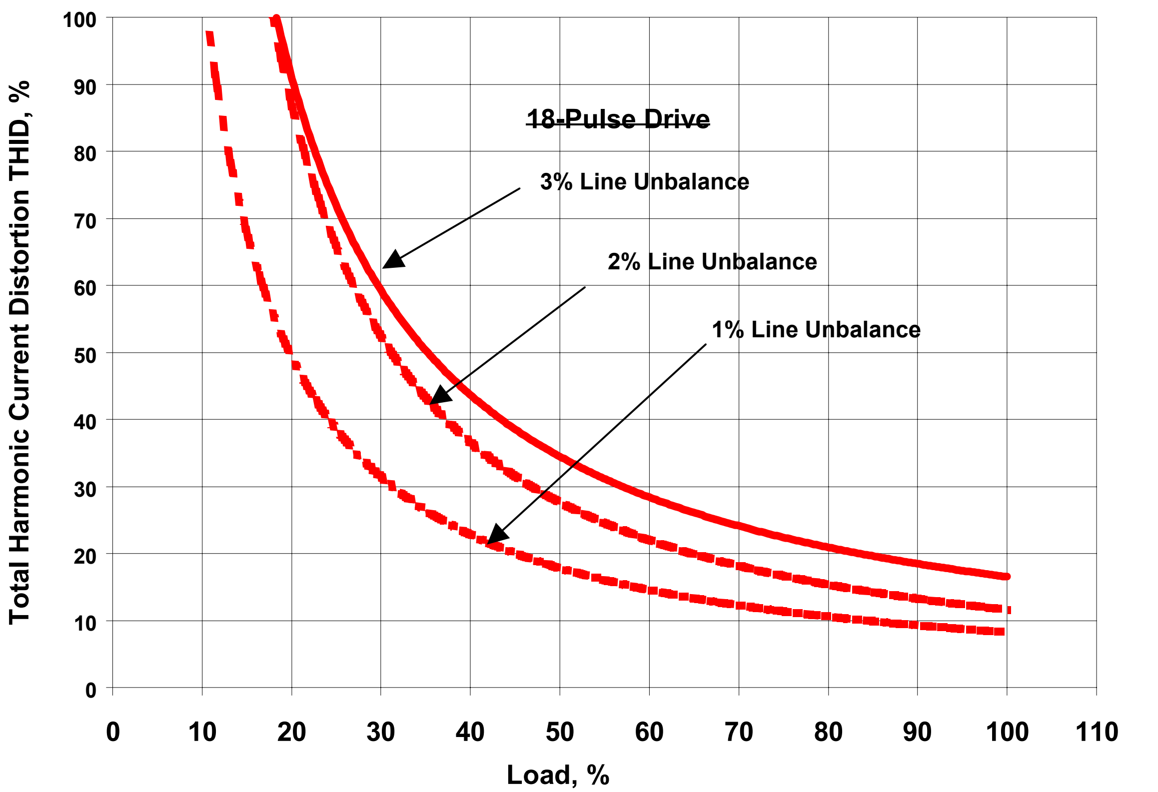
Fig. 9 Harmonic spectrum for 18-pulse rectifier, measured while *operating at full load*, when line voltages were balanced.

5.3 Effects of Unbalanced Line Voltage on 18-pulse Rectifiers

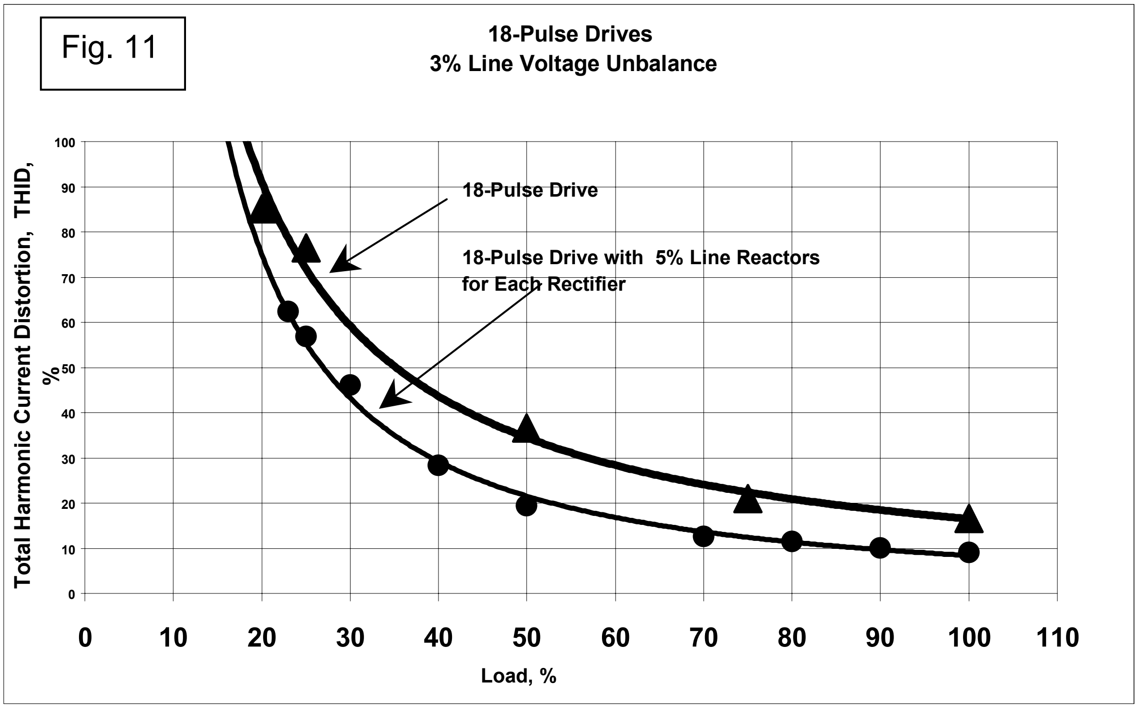
Similar to twelve pulse systems, 18-pulse rectifiers experience diminishing performance when line voltages are not balanced, and when operating at less than full load. 18-pulse drives may offer guaranteed harmonic distortion levels, but typically only at full load and full speed conditions, with voltages that are balanced within one percent. Fig. 10 illustrates the effect of unbalanced line voltages on 18-pulse drives operating between full load and no load conditions.

Fig. 10

18 Pulse Drive- with Line Voltages Unbalanced by 1% to 3%



Notice that as the load is decreased the magnitude of percent harmonic distortion increases significantly. While %THID at full load may be fairly low, at 40% load, harmonic current distortion was measured to be over 20%THID, when the line voltages were only one percent unbalanced. When the line voltage unbalance was three percent, the harmonic current distortion increased to over 40%THID. To enhance the performance of 18-pulse drives, line reactors may be added in series with the individual bridge rectifiers. This is demonstrated in *Fig. 11*.



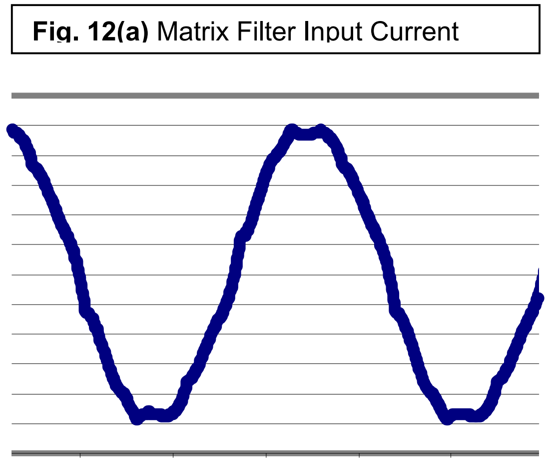
6 Matrix Harmonic Filters

6.1 Theory of Operation

Matrix Harmonic Filters are low pass, passive harmonic filters. They connect in series at the input to any six pulse drive. Being a low pass filter, the Matrix Filter attenuates each harmonic frequency, resulting in the lowest harmonic distortion levels of any passive filter. Their performance, in real life operating conditions such as unbalanced line voltages and from no load to full load is superior to all of the passive techniques discussed previously in this paper. Typical losses associated with Matrix Harmonic Filters are less than one percent of the load power rating. These low pass filters do not cause power system resonance problems and do not attract harmonics from other non-linear loads sharing the same power source. Harmonic distortion performance guarantees are offered for variable frequency, variable torque applications.

6.2 Matrix Filter Performance

Matrix filters convert any six pulse drive to harmonic mitigation performance that is better than 18-pulse rectification. The typical input current waveform and harmonic spectrum are demonstrated in *Fig. 12(a)* and *Fig. 12(b)*.



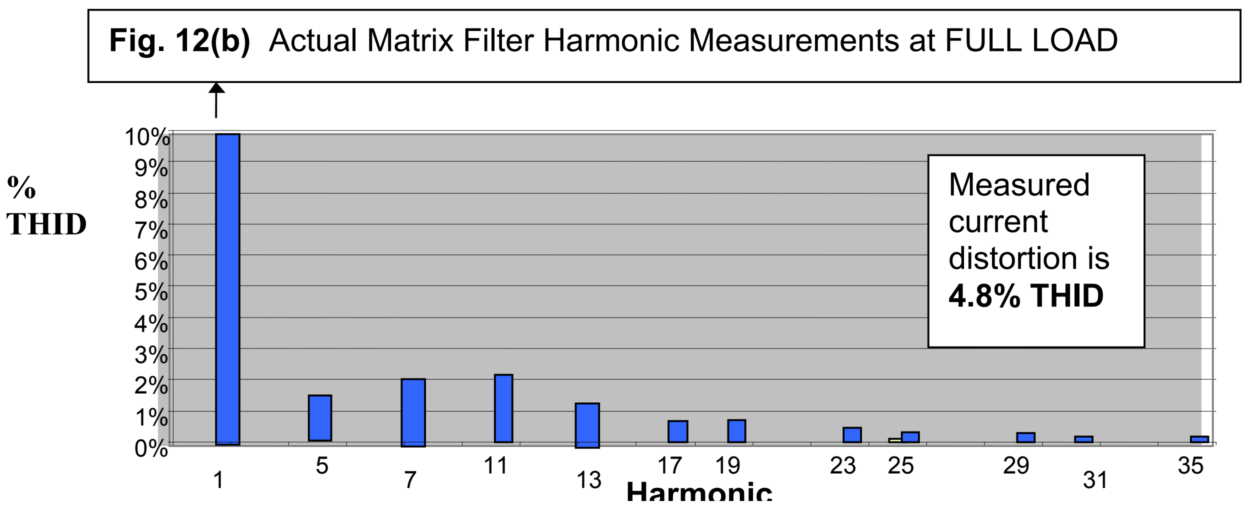
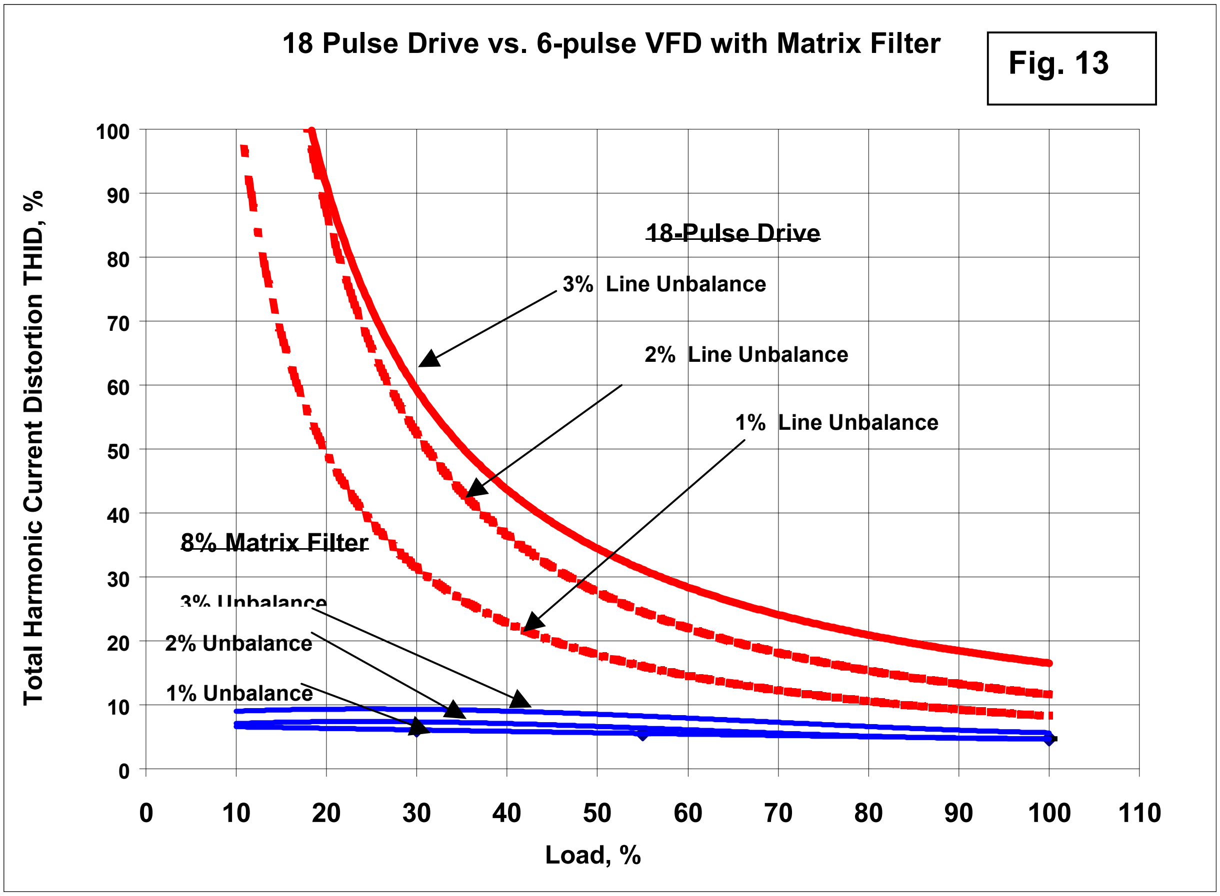


Fig. 12(b) Input current spectrum for 6-pulse drive with Matrix Filter.

6.3 Matrix Filter Performance with Unbalanced Line Voltage

Due to their internal series reactance, component tolerances and circuit configuration, Matrix Filters are only mildly affected by unbalanced line voltage conditions. It is also apparent in *Fig. 13*, that Matrix Filter performance is quite consistent from no load to full load conditions. This is demonstrated by the comparison of Matrix Filters to the 18-pulse drives previously discussed. The combination of six pulse VFD and Matrix Filter attenuated harmonics better than the eighteen pulse drive, when tested with various percentages of line voltage unbalance, and when operating at load conditions ranging from 0% to 100% load. By comparison of *Fig. 11* and *Fig. 13*, the six pulse drive with Matrix filter also reduced harmonics to lower levels than the enhanced 18-pulse drive, which used additional line reactors.



7 TRIPLEN HARMONICS

Triplen harmonics are typically not present in a balanced three phase system. They occur however when the line voltages are not balanced, or when the line voltage is distorted by non-linear single phase loads. The presence of triplen harmonics increases the resultant THID level for virtually any passive harmonic mitigation equipment. Some mitigation techniques, such as multi-pulse drives, are highly sensitive to voltage unbalance as demonstrated in *Fig. 8, Fig. 11* and *Fig. 13*. Tuned 5^{th} harmonic traps also experience significantly elevated %THID levels when line voltages are not balanced, as demonstrated in *Fig. 6*. Matrix Filters achieve better attenuation of harmonics under real life operating conditions because they are only minimally influenced by unbalanced line voltages, as demonstrated by *Fig.13*. Additionally, they provide superior harmonic mitigation performance at operating conditions that range from no load to full load.

8 CONCLUSION

Electrical system reliability and normal life expectancy of electrical equipment rely heavily upon a clean and reliable power supply. Those wishing to maximize productivity through utilization of clean power technologies have several harmonic mitigation techniques available. Each technique has a different cost, power loss, and harmonic distortion reduction benefit. Some solutions, such as Matrix Harmonic Filters provide

harmonic performance guarantees, while others may require extensive analysis. This paper demonstrates that theoretical performance is not necessarily a valid estimate of the actual expected performance of most mitigation techniques when operating under real life conditions. The performance level of most techniques diminishes in the real world due to the presence of unbalanced line voltages and operation at less than 100% loading conditions.

APPLICATION NOTE

July 2002

Doc. #AN0105

Solving DC Drive Harmonics with Matrix Harmonic Filters

Matrix Filters may be used for phase controlled DC drive applications to improve power factor and reduce line harmonics. Application to DC drives is similar to AC drives with a few important differences in filter performance and the selection of the appropriate filter rating. The following paragraphs cover these differences.

Matrix Filter Selection

Selection of the proper Matrix Filter rating for a DC drive is based on the horsepower and voltage rating of the drive. Applications for DC motors rated at 500 volts or higher may use a 480 VAC filter rated at the same horsepower as the DC drive provided the motor efficiency is a minimum of 85%. DC motors with lower efficiencies will typically draw higher ac input current and therefore a Matrix Filter rated for higher horsepower may be required. The following equation should be used to select the correct filter rating:

$$\boxed{\textbf{Matrix Filter HP} = \frac{\textbf{DC Drive HP x 85\%}}{\textbf{DC motor efficiency}}}$$

If the calculated filter horsepower falls between two standard horsepower ratings, the next larger filter rating should be selected. This will insure that the drive may be used at full rated horsepower without overheating the Matrix Filter components. Do not use this equation to downsize the Matrix Filter when motor efficiencies are greater than 85%. The same type of scaling is necessary for motors with armature voltage ratings less than 500 volts. To select a Matrix Filter for a DC drive, when the motor armature voltage is less than 500 volts use the following equation.

$$\boxed{\textbf{Matrix Filter HP} = \frac{\textbf{DC Drive HP x 500Volts}}{\textbf{Rated Armature Voltage}}}$$

If the calculated filter horsepower falls between two standard horsepower ratings, the next larger filter rating should be selected.

Matrix Filter Performance

Matrix Filters are suitable for use with DC drives and other phase controlled rectifier applications, but harmonic performance will vary based upon controller output voltage (speed) and output current (load). While it is not possible to specify guaranteed levels of harmonic distortion for Matrix Filters used with phase controlled SCR applications, Matrix filters are extremely effective at solving harmonics problems associated with DC Drives and other six-pulse phase controlled rectifiers.

The performance of the Matrix Filter with a DC drive differs from that with an AC drive due to two main factors: (1) the harmonic content of the DC drive line current waveform tends to have higher amplitude harmonics at the 11^{th} and higher, and (2) the line current of the DC drive is mainly dependent on motor torque, not motor power. The effect of these differences is an increase of about 10% - 50% in THID under full torque conditions and a noticeable rise in THID during lightly loaded low speed operation. Although for this reason, the Matrix Filter performance guarantee does not apply to DC drive applications, Matrix Filters are very effective at solving DC drive harmonic problems.

This rise in percent distortion is not due to an increase in absolute harmonic current, but results from the cancellation of the lagging fundamental drive current with the leading filter capacitor current. See figures 1, 2, and 3 for nominal THID curves of a 500-volt DC motor at 100%, 50%, and 10% speed. In this example the drive is operating from a nominal 480 VAC line.

FIG. 1

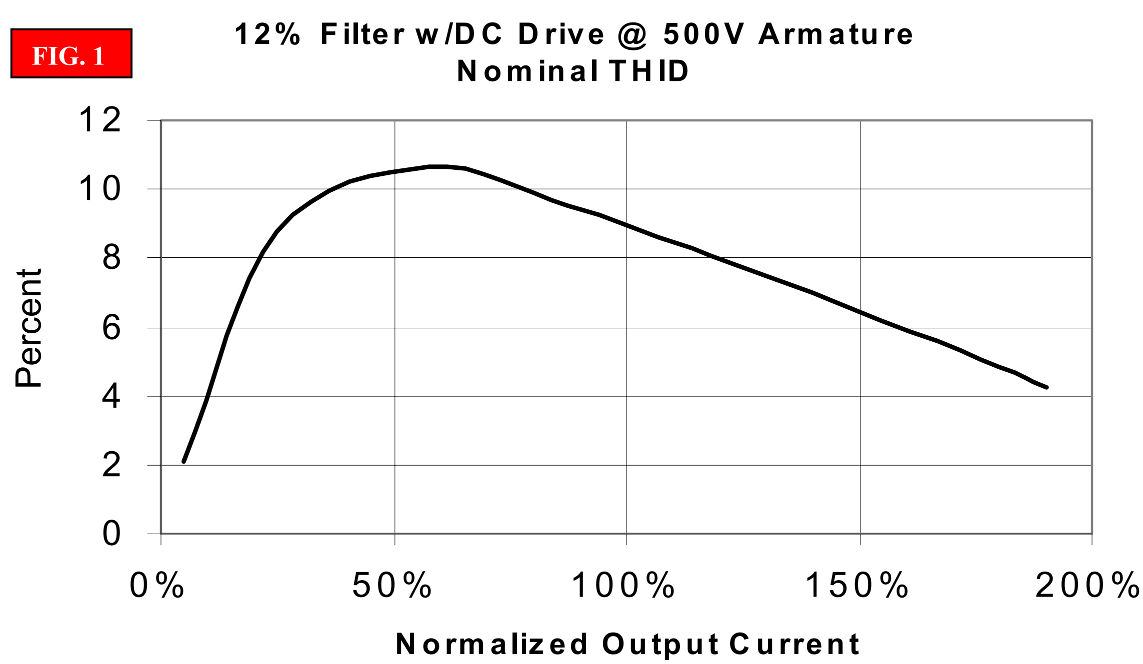


FIG. 2

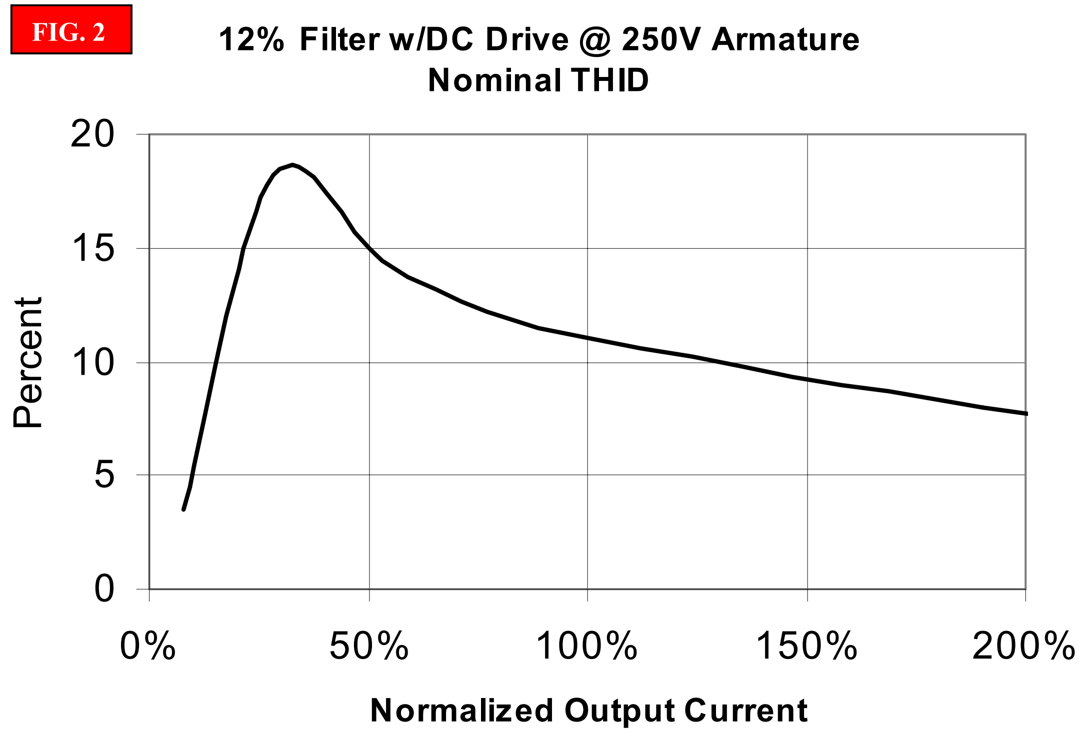
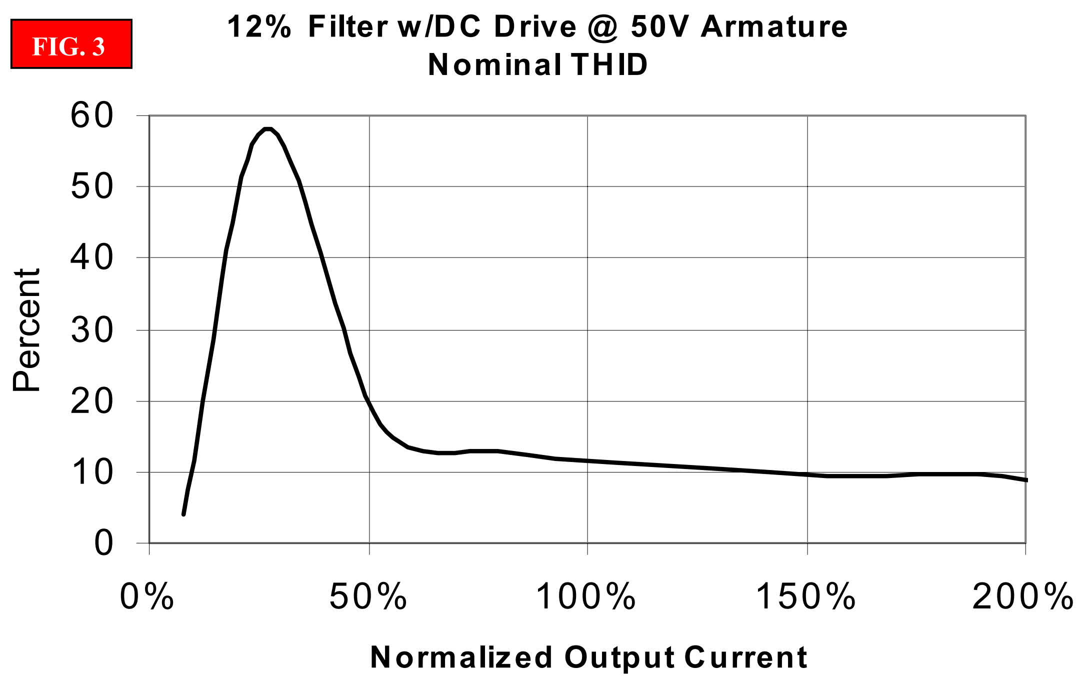

12% Filter w/DC Drive @ 250V Armature
Nominal THID
Percent
20
15
10
5
0
0%
50%
100%
150%
200%
Normalized Output Current

FIG. 3


12% Filter w/DC Drive @ 50V Armature
Nominal THID
Percent
60
50
40
30
20
10
0
0%
50%
100%
150%
200%
Normalized Output Current

Available Motor Overload Current

The limitation on available motor overload current with a Matrix Filter on a DC drive depends on many of the same factors as an AC application. Rated motor voltage, operating speed, line impedance, and filter type are all important parameters. The worst case conditions are full armature voltage, low line voltage, high line impedance, and an 8% versus a 12% filter. Figures 4 and 5 show the worst case available currents with 6% line impedance as armature percent resistance varies. Figures 6 and 7 are the same curves with 3% line impedance.

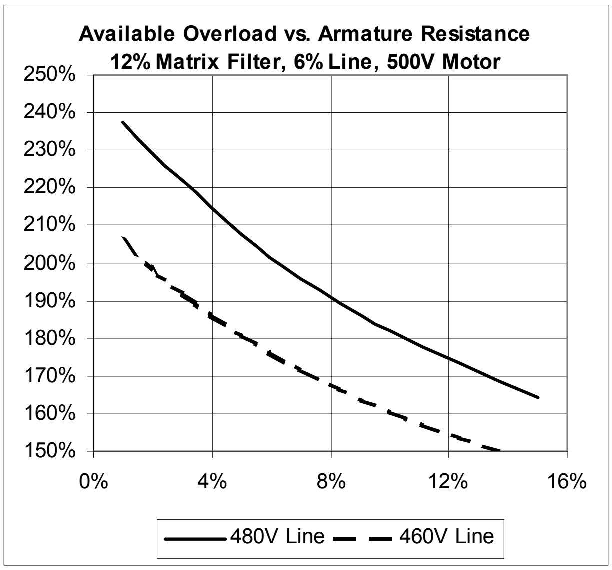


Figure 4

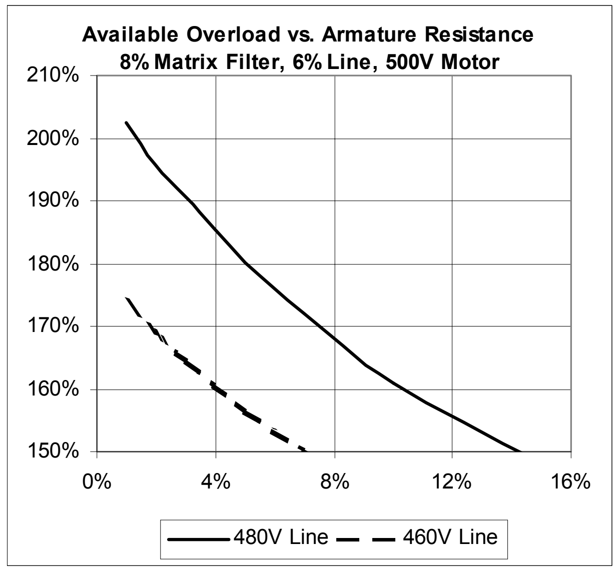


Figure 5

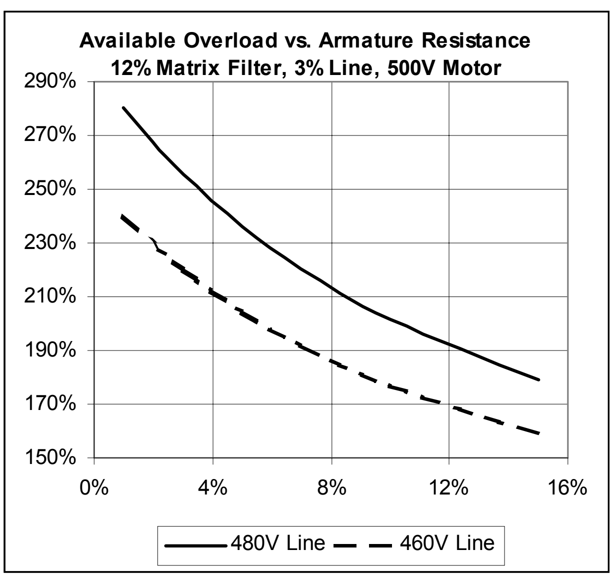


Figure 6

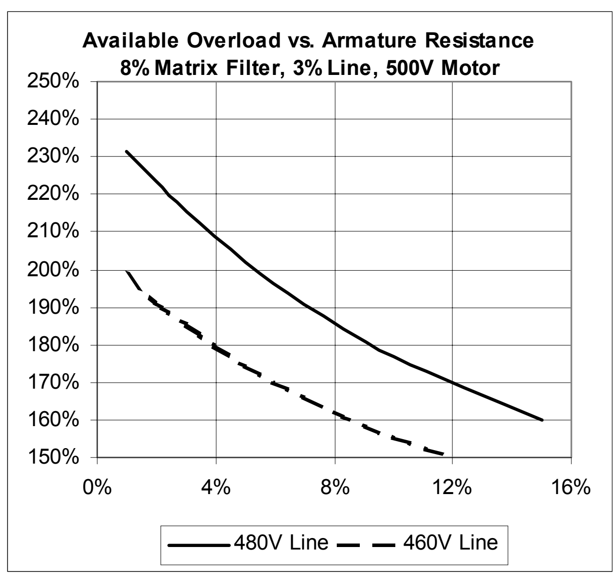


Figure 7

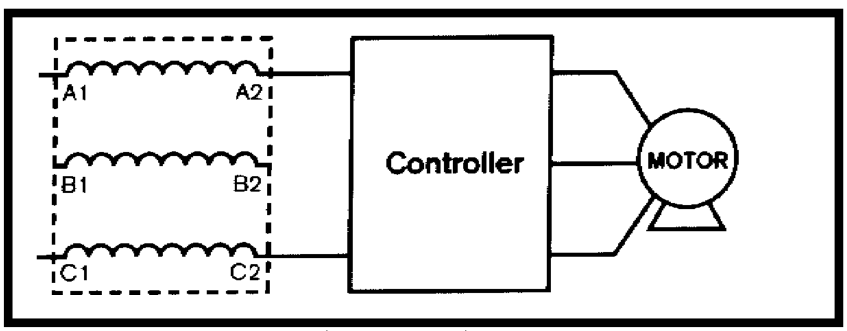
APPLICATION NOTE

How to use a 3-phase line reactor for a single-phase application!

The illustration below demonstrates how a 3-phase line reactor can be used for a single-phase application. Using the mathematical method below you can calculate the inductance to determine what type of reactor is needed.

Reactors for Single Phase Applications

MTE three-phase Line / Load Reactors can be used for single-phase applications by routing each of the two supply conductors through an outside coil, and leaving the center coil disconnected. For the drive input application shown in (Figure 1.), the incoming supply lines connect to terminals A1, C1, and outgoing lines from A2, C2. The "B" terminals for the center coil are not connected. The sum of the inductance of the two coils is the total inductance applied to the circuit.



(Figure 1.)

As an example, consider a single-phase application of 2HP supplied by 240 Vac. The reactor must carry 12A (fundamental current) according to the NEC table for single-phase motor current. A 5% impedance is desired. For a 60Hz supply, the formula to calculate required inductance is: $L = (ZV) / (377I)$, where L is inductance in Henries, Z is percent impedance, V is supply voltage, and I is full load amps.

For above example: $0.00265 = (0.05 \times 240) / (377 \times 12)$, indicating a total required inductance of 2.65 mH. Based upon this result, MTE part number RL-01201, which has an inductance per coil of 1.25mH, a fundamental current rating of 12A, and a maximum continuous current rating of 18A, will work. When connected for a single-phase application, the sum of the two coils will provide a total inductance of 2.5mH, or an effective impedance of 4.7%, calculated as $Z = (I \times 377 \times L) / V$, or $.047 = (12 \times 377 \times .0025) / 240$. For a 50Hz supply, modify the formulas by substitution of the factor 314 in place of 377.

SELECTION TABLE

SINGLE-PHASE MOTOR DRIVE APPLICATIONS

HP	120 V	208 V	240 V	480 V
1/6	RL-00801	RL-00401	RL-00402	RL-00202
1/4	RL-00801	RL-00401	RL-00401	RL-00202
1/3	RL-01201	RL-00401	RL-00401	RL-00201
1/2	RL-01801	RL-00801	RL-00802	RL-00403
3/4	RL-02501	RL-00801	RL-00801	RL-00402
1	RL-02501	RL-01201	RL-00801	RL-00402
1-1/2	RL-03501	RL-01201	RL-01201	RL-00803
2	RL-03501	RL-01801	RL-01201	RL-00803
3	RL-05501	RL-02501	RL-01801	RL-01202
5	RL-10001	RL-03501	RL-03501	RL-01802
7-1/2	RL-13001	RL-04501	RL-04501	RL-02502
10	RL-13001	RL-05501	RL-05501	RL-02502
15		RL-08001	RL-08001	RL-03502
20		RL-10001	RL-10001	RL-04502
25		RL-13001	RL-13001	RL-05502
30				RL-08002
40				RL-10002
50				RL-13002

These selections provide typical percent impedance rating of 5%.